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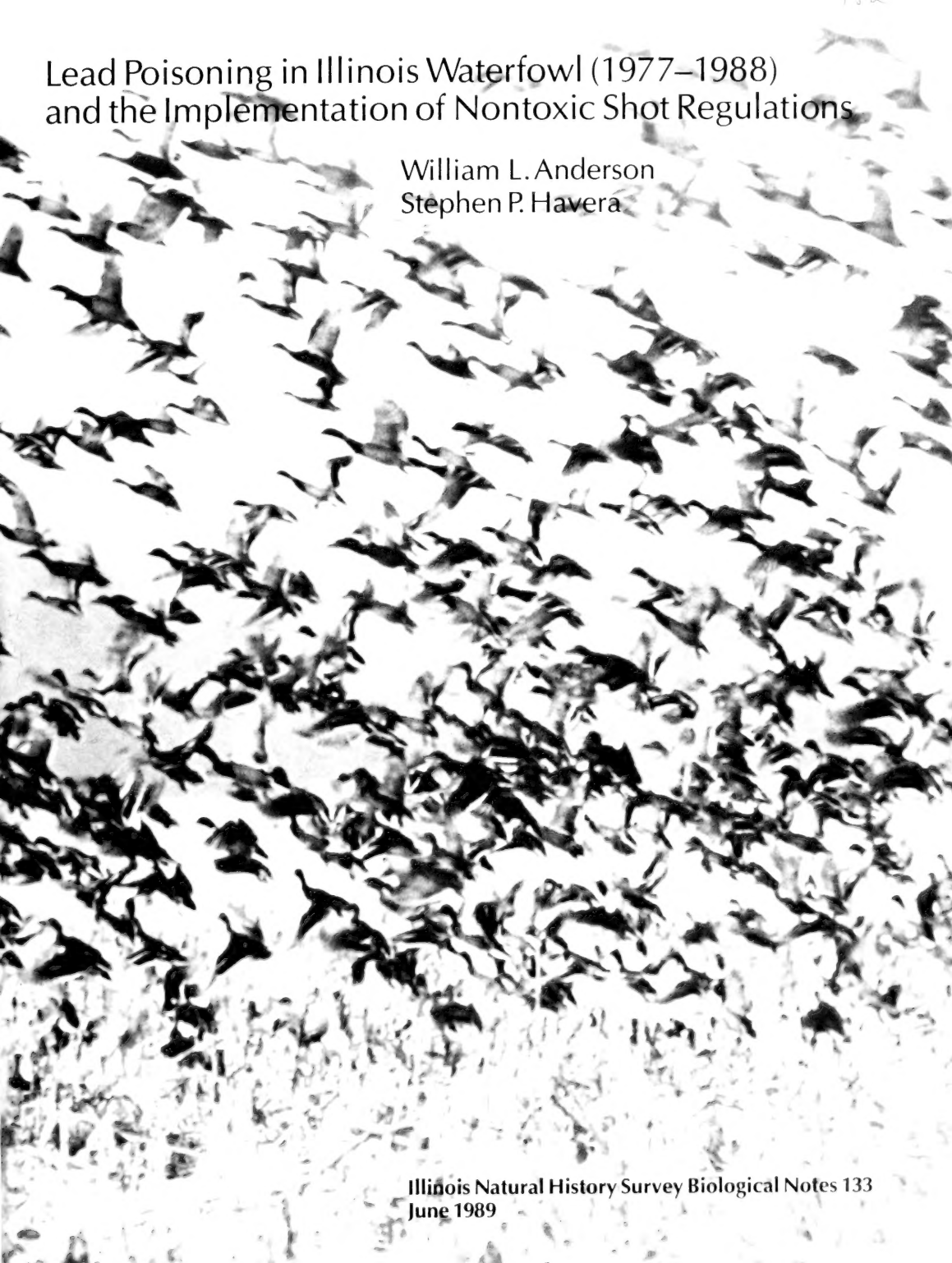

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William L. Anderson and Stephen P. Havera

For more than a century, waterfowl have ingested spent lead shot while feeding and suffered lead poisoning as a result (Phillips and Lincoln 1930:164). First noted in Texas about 1874, the disease was documented in North Carolina before 1901, in Washington before 1908, in Virginia and Utah in 1915, in Indiana, Oregon, Louisiana, Arkansas, and Michigan by 1928, and in South Dakota by 1935 (Bellrose 1959:238–239). The first recorded lead poisoning die-off in Illinois occurred in January of 1940 along the Illinois River at Henry and consisted of 200–300 mallards (scientific names for animals and plants mentioned in this publication are found in Appendix A) (Bellrose 1959:240).

In his definitive study of lead poisoning, Bellrose concluded that annual losses attributable to lead poisoning totaled 2–3% of the fall population of waterfowl in North America, that the disease occurred more commonly in the Mississippi Flyway than in the other flyways, and that the mallard—the most heavily hunted species—was the principal victim (Bellrose 1959:282). His estimates of losses among the fall population of mallards were 4% in the Mississippi Flyway and 3–4% in the other three flyways.

Most die-offs from lead poisoning occur during the late fall and early winter months after the close of the hunting season (Bellrose 1959:246). At that time, waterfowl return to feed in areas that have been hunted and where spent shot is plentiful. Because waterfowl make limited use of those areas during the hunting season, the food supply often remains relatively abundant and proves attractive when the hunting season ends (Fig. 1).

The clinical symptoms of lead poisoning in waterfowl have been described in numerous earlier publications (e.g., Sanderson and Bellrose 1986), but four typical effects of the disease are shown in Figure 2. In more recent studies, neurological dysfunctions and other sublethal consequences of lead poisoning in waterfowl have been described (Dieter and Finley 1978; Dieter 1979; Roscoe et al. 1979; Sanderson et al. 1981). The endangered bald eagle, a winter resident in Illinois (Havera and Kruse 1988), also suffers from lead poisoning acquired by ingesting shot as it feeds on hunter-crippled and lead-poisoned waterfowl (U.S. Department of the Interior 1986).

The mandatory use of nontoxic (steel) shot for waterfowl hunting was initiated in some areas of the Atlantic Flyway in 1976, in some areas of the Mississippi Flyway in 1977, and in some areas of the Central and Pacific flyways in 1978. These regulations prompted studies in many states, including Illinois, to determine the current distribution and severity of lead poisoning among waterfowl. Studies in Illinois considered the abundance of spent shot in soil and sediment, the incidence of ingested shot in gizzards of hunter-harvested birds, the incidence of above-background concentrations of lead and protoporphyrin in blood (i.e., concentrations greater than those in waterfowl not subject to lead shot ingestion or lead poisoning die-off), the incidence of above-background concentrations of lead in livers, and the occurrence of die-offs attributed to lead poisoning. Our report summarizes and compares the results of the Illinois studies (Anderson 1982a,b, 1983, 1986b; Anderson and Havera 1985; Anderson et al. 1987) and addresses the following issues: (1) the distribution and severity of lead poisoning in waterfowl in Illinois; (2) the prevalence of lead poisoning over the past 40 years; (3) the dynamics of lead poisoning die-offs; (4) the use of nontoxic shot in reducing the potential for lead poisoning; and (5) the incorporation of findings from studies in Illinois and elsewhere into complex policy-making decisions over the past ten years—the critical decade of transition in the adoption of nontoxic shot regulations for the sport hunting of waterfowl in the United States.

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FIGURE 1a. Waterfowl ingest spent shot by feeding in hunted areas. In the two photos above, hunters discharge shot into waterfowl habitat. A spread of decoys is shown in each situation.

FIGURE 1b. During the hunting season, waterfowl feed in hunted areas before and after legal shooting hours. In addition, ducks and geese often feed in these areas after the hunting season. Because spent shot is plentiful in these situations, the birds are particularly vulnerable to lead poisoning.

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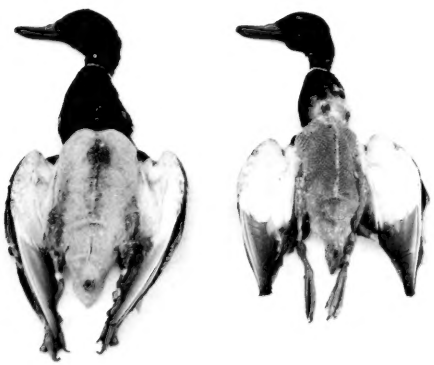

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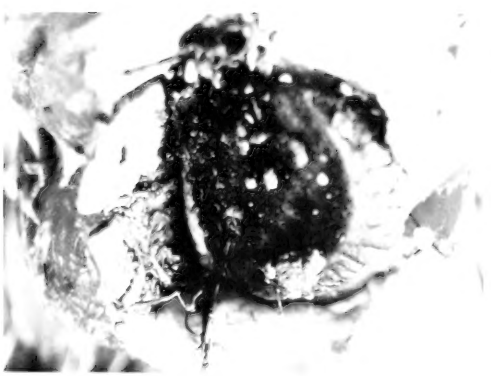

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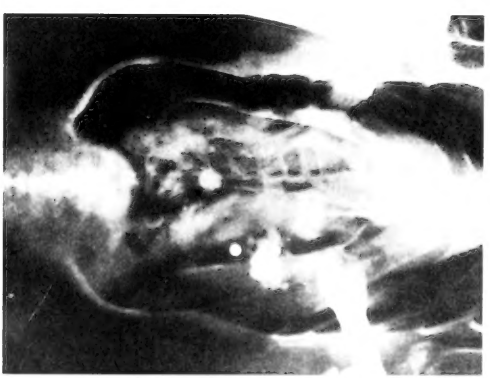

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FIGURE 2. Indications of lead poisoning in waterfowl: (a) birds dying in hunted areas, (b) wings assuming a "roof-shaped" position over the back, (c) reduction in body weight, (d) food impaction of the proventriculus, (e) ingested shot in a duck gizzard, and (f) ingested shot in the gizzard of a duck as shown by X ray. Photo (b) from Friend 1987; (c), (d), and (f) from Jordan and Bellrose 1951.

Methods

In this report, measurements (metric or English) are given first in the form in which they were originally recorded; conversions are given second.

Determining Spent Shot in Soil and Sediment

A total of 460 soil and sediment samples were randomly collected on three managed hunting areas (waterfowl, put-and-take pheasant, and mourning dove) and examined for spent shot. The waterfowl area (215 samples, 27 April–17 May 1982) was the Casey Fork Subimpoundment at Rend Lake in Jefferson County (Fig. 3), a site where 350–500 Canada geese and 100–150 mallards died from lead poisoning in March 1981. About 90% of this 1,450-acre (587-ha) area is flooded each October to attract ducks and geese for hunting. The pheasant area (105 samples, 6–12 May 1983), located in Wayne Fitzgerrell State Park adjacent to Rend Lake (Fig. 3), was investigated to determine if spent shot there contributed to the lead poisoning of waterfowl and whether lead poisoning is a problem for bobwhite and other upland birds on this area. Portions of this 1,500-acre (607-ha) tract are inundated when Rend Lake exceeds normal pool. The dove hunting area (150 samples, 5 July and 4 October 1979) was a 35-acre (14.2-ha) field in Sam Parr State Park, Jasper County (Fig. 3). This field, planted to sunflowers each growing season, was studied to evaluate the potential danger of lead poisoning to mourning doves and to provide information on waterfowl areas where sunflowers are planted in an attempt to improve dove hunting.

Each sample was collected by pressing a square (12 × 12 inches, 30.5 × 30.5 cm) angle-iron frame flush into the soil or sediment (dewatered areas) and trenching around it. The frame was removed and the upper 0.5, 1.0, or 2.0 inches (1.3, 2.5, or 5.1 cm) of soil or sediment were skimmed off with a flat-bottomed shovel. The sample was placed in a plastic bag (12 × 18 inches, 30.5 × 45.7 cm), labeled, and stored in a rodent-proof facility until processing (Fig. 4).

Each sample was placed in a 5-gallon (18.9-liter) plastic bucket and soaked in water for several hours. Vegetative material that floated was removed. The remainder of the sample was poured into a 0.05-inch (1.27-mm) mesh sieve and washed with pressurized water to remove fine materials. The "residue" (small rocks, grit, shot, and other relatively large and heavy materials) was returned to the bucket, air dried, packaged in plastic bags (8 × 10 inches, 20.3 × 25.4 cm), and X-rayed or fluoroscoped. Samples that contained dense objects were examined visually to verify the presence or absence of shot. The size, composition, and other characteristics of each pellet were recorded.

Examining Gizzards for Shot

During the 1979–1985 hunting seasons, gizzards were collected from 13,779 hunter-harvested mallards at 29 locations in Illinois, from 1,385 lesser scaups at 8 locations, and from 887 Canada geese at 3 locations (Fig. 5). Gizzards were also taken from 37 redheads and 83 ring-necked ducks. In 1979, 3,408 gizzards were processed; in 1980, 3,837; in 1981, 2,934; in 1982, 2,835; in 1983, 1,572; in 1984, 669; in 1985, 916. Collecting sites were located in 37 (36.3%) of the 102 counties in Illinois; those 37 counties accounted for 70.2% of the statewide waterfowl harvest in 1971–1980 (Carney et al. 1983). The annual harvest averaged 419,496 ducks and geese in Illinois during this ten-year period.

Each gizzard, which had been frozen or preserved in 95% ethanol, was opened and its contents flushed into a bowl 24 cm (9.4 inches) in diameter (Fig. 6). Food and other light-weight materials were separated into a 0.25-mm (0.0098-inch) sieve with a 30-cm (11.8-inch) diameter; grit and other heavy material remained in the bowl. Each gizzard lining was inspected

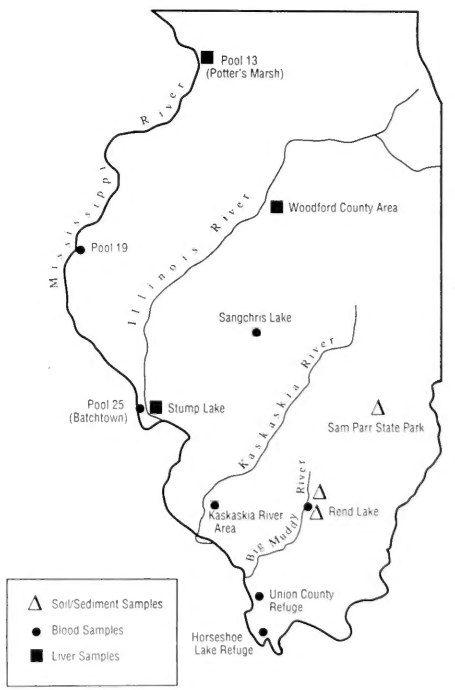

FIGURE 3. Areas from which soil/sediment, blood, and liver samples were taken.

Figure 4. (a) Equipment used to determine abundance of spent shot in soil and sediment on public hunting areas in Illinois (b) using a shovel and plastic bag to collect a sample of sediment (dewatered), (c) preparing the sample for soaking, and (d) washing the sample to remove all material except shot, grit, and other relatively coarse objects.

for pellet holes from the charge that killed the bird and for discolorations and sloughing, both of which indicated the ingestion of lead shot and lead poisoning. Food and grit samples from each gizzard were placed on separate paper towels, and each grit sample was visually examined for shot. In most instances, the physical characteristics of the shot revealed whether it had been ingested (pitted or scoured, undersized, brightly colored) or shot into the gizzard (angular or burred, full-sized, dark blue-gray). If a pellet suspected to have been shot into a gizzard was found but no hole was detected in the gizzard lining, the lining was removed and several sections were made through the gizzard muscle to determine if holes had been overlooked. Failure to find a hole, however, did not preclude classifying a pellet as shot-in. The grit and the food samples were then transferred to a tray, numbered sequentially, and air dried for at least 24 hours.

Each dry grit sample was sealed in a plastic bag and X-rayed. Dense objects appearing on the X rays were examined visually to determine if they were shot. Dry food samples were packaged individually in plastic bags and fluoroscoped; those containing dense objects were examined visually.

Analyzing Blood for Lead and Protoporphyrin

Blood was taken from 2,265 waterfowl (1,137 mallards, 264 canvasbacks, and 864 Canada geese) at seven locations in Illinois between March 1981 and February 1983 (Fig. 3). Birds were captured in swim-in traps baited with corn. Blood (1–2 ml) was extracted from the brachial vein of each bird with a 2.5-ml syringe equipped with a heparinized 20-gauge needle. A portion (4–5 drops) of each sample was blotted onto Whatman #1 filter paper and dried; discs were cut from these blots and analyzed for concentrations of lead with an atomic absorption spectrophotometer equipped with a Delves cup (Joselow and Bogden 1972). The remainder of the fresh sample was placed in a heparinized vial (2-ml Vacutainer), oxygenated, refrigerated for ≥2 days, and then analyzed for concentrations of protoporphyrin with an Aviv Hematofluorometer calibrated for waterfowl blood (Roscoe et al. 1979). This procedure is illustrated in Figure 7. Protoporphyrin, a metabolic precursor to hemoglobin, increases in response to lead poisoning in ducks and geese (Roscoe et al. 1979). Thresholds for concentrations in wet blood above background levels were 0.2 ppm of lead and 40 ug/dl of protoporphyrin (Roscoe et al. 1979:135; U.S. Department of the Interior 1986:H-10; *Federal Register* 50:19271, 7 May 1985).

Analyzing Liver for Lead

Livers were collected from 335 mallards harvested at three locations in Illinois during the 1985 hunting season (Fig. 3). Because gizzards were also taken from these mallards (and examined for ingested shot), the livers and gizzards were identified as paired samples from individual birds. Liver tissues were analyzed for concentrations of lead via atomic absorption spectrophotometry (Locke et al. 1982). The threshold selected for concentrations in wet liver above background levels was 2.0 ppm of lead (U.S. Department of the Interior 1986:H-10; *Federal Register* 50:19271, 7 May 1985).

Documenting Die-offs Attributed to Lead Poisoning

Data were compiled on all known lead poisoning die-offs of waterfowl in Illinois during 1977–1986. In most instances, wildlife biologists from the Illinois Department of Conservation, the Illinois Natural History Survey, or the U.S. Fish and Wildlife Service investigated the environmental conditions at the site, counted afflicted birds, salvaged specimens, estimated the number of waterfowl lost, and surveyed the size and species composition of the populations using the area. Samples of sick or dead birds were sent for necropsy to the National Wildlife Health Laboratory, Madison, Wisconsin, or to other diagnostic facilities.

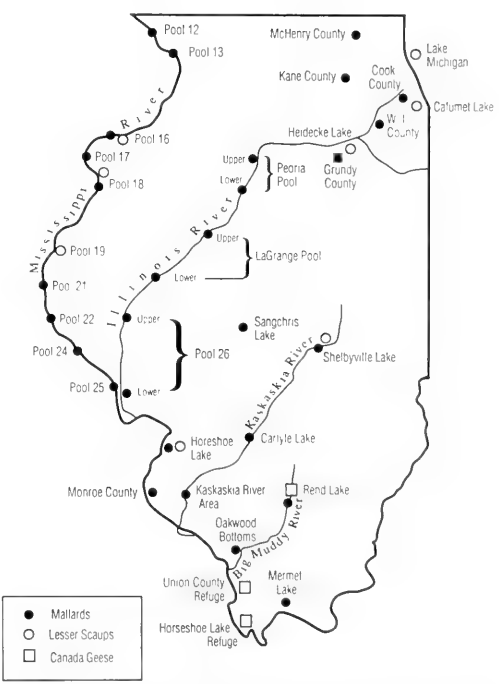

FIGURE 5. Areas where gizzards were collected from waterfowl, 1979–1985.

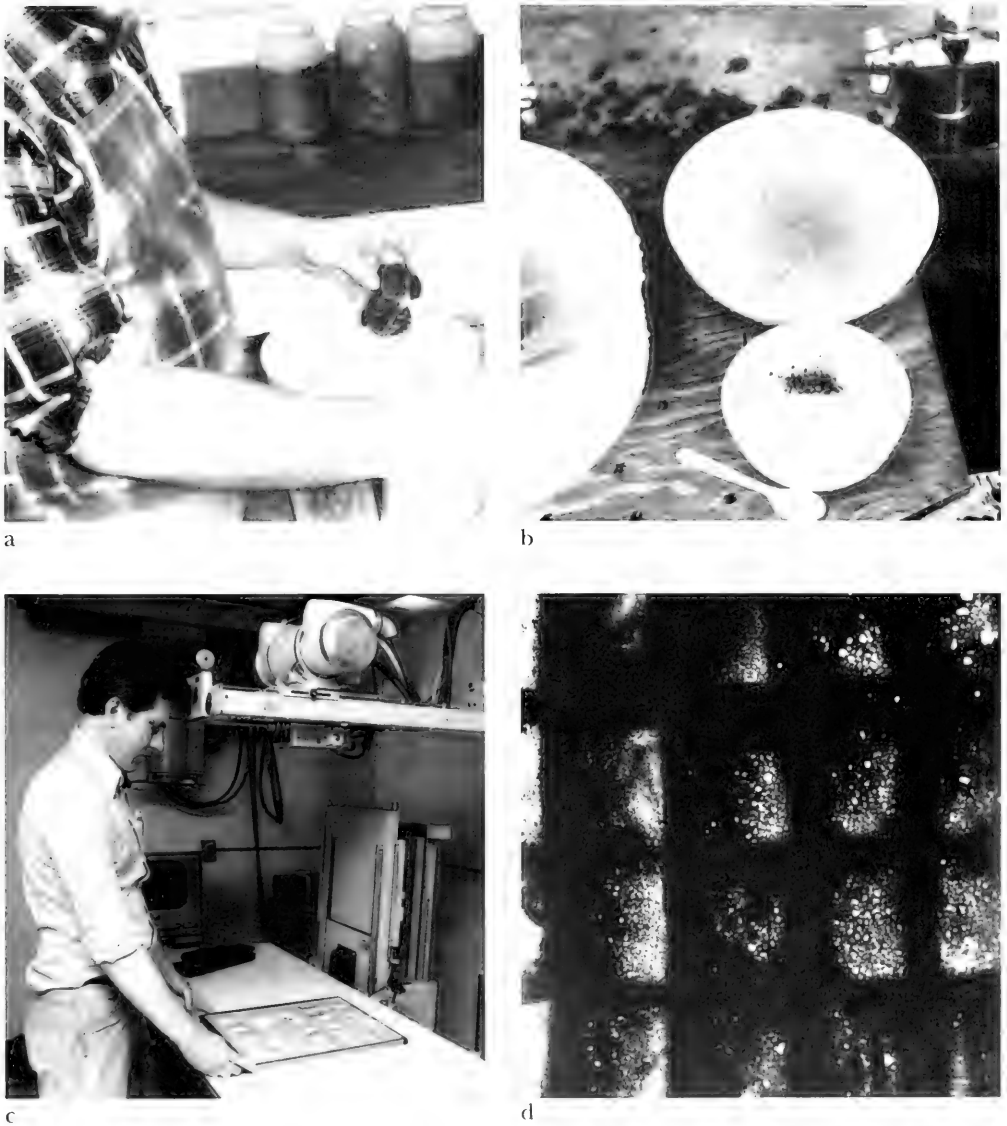

Figure 6. Procedures used to examine gizzards from hunter-harvested waterfowl for the presence of ingested shot. (a) removing contents from a gizzard, (b) separating contents into grit and food, and (c) X-raying grit samples. The X ray of a tray of grit samples (the bright images in the samples are shotgun pellets) is shown in photo (d).

FIGURE 7. Procedures used to analyze blood from live-trapped waterfowl for concentrations of lead and protoporphyrin: (a) the birds were captured in swim-in traps such as this one at Rend Lake; photos (b) and (c) show blood being taken from the brachial veins of a Canada goose and a mallard; (d) illustrates how samples were stored on Whatman filter paper and in heparinized vials; (e) pictures the atomic absorption spectrophotometer with a Delves cup used to analyze discs from the filter paper for concentrations of lead; (f) shows the hematofluorometer used to analyze fresh blood for concentrations of protoporphyrin.

Results

Data on lead and steel shot are presented in three categories: spent shot recovered from soil and sediment, ingested shot in gizzards, and shot-in pellets in gizzards. In addition, data from blood and liver samples are presented in this section as are descriptions of die-offs associated with lead poisoning.

Spent Shot in Soil and Sediment

Results are reported here according to the three managed hunting areas described earlier.

Waterfowl Hunting Area. A total of 186 spent shot (165 lead and 21 steel) were found in the 215 soil and sediment samples collected from the Casey Fork Subimpoundment at Rend Lake in April–May 1982 (Table 1). This number equates to an average of 37,700 shot per acre (93,155 per ha) or 1 pellet per 1.16 square feet (1 pellet per 0.1 m^2) in the upper 1 inch (2.54 cm) of soil or the upper 2 inches (5.1 cm) of sediment. Spent shot was most abundant, averaging 75,800 pellets per acre (187,299 per ha), in a flooded field that had been left fallow the previous growing season. Spent shot was also abundant, averaging 36,900 pellets per acre (91,179 per ha), in an unflooded corn field used as a firing line by goose hunters. In two less heavily hunted fields, spent shot averaged 16,600 and 21,800 pellets per acre (41,018 and 53,867 per ha), respectively.

Of the lead shot found in the Casey Fork Subimpoundment, 38.5% were sizes BB and No. 2; 54.8% were sizes No. 4, No. 5, and No. 6; and 6.5% were sizes No. 7 ½, No. 8, and No. 9. Of the steel shot, 55.0% were sizes BB and No. 1, and 45.0% were sizes No. 2 and No. 4. Steel shot pellets, which had been required in 12-gauge shells for waterfowl hunting on the area in 1977 and 1978, were in advanced stages of corrosion.

For purposes of comparison, we offer earlier data on the incidence of spent shot on waterfowl hunting areas outside of Illinois. The abundance of spent shot in soil on 24 areas in seven states and provinces ranged from 0 to 118,048 pellets per acre (0 to 291,693 per ha), with a median of 20,255 per acre (50,049 per ha) (Bellrose 1959:251). Approximately 30,000 pellets per acre (74,129 per ha) were estimated for soils at Catahoula Lake, Louisiana, in 1963 (Wills and Glasgow 1964), and an estimated 23,000 to 122,000 pellets per acre (56,832 to 301,458 per ha) were present in front of duck blinds at the Duck Creek Wildlife Area in Missouri (Fredrickson et al. 1977). In the Pacific Flyway, the soil in 8 of 25 national wildlife refuges had pellet densities in excess of 100,000 per acre (247,097 per ha) in 1974–1977; on Grizzly Island Wildlife Management Area in California, a density of 435,000 pellets per acre (1,074,870 per ha) was measured (U.S. Department of the Interior 1986:III-16).

Although the number of lead shot in soil sufficient to constitute a hazard to waterfowl has not been defined, we believe the threshold is about 20,000 pellets per acre (49,419 per ha), or about 1 pellet per 2 square feet (0.2 m^2) of soil. When shot accumulates to that level, mallards and other species that forage several inches into sediment can be expected to ingest spent shot at relatively high rates. The die-offs of 3,400–3,500 Canada geese at Horseshoe Lake (Alexander County) and Union County refuges during January–February 1977 occurred on areas that had 17,424 and 44,431 spent pellets per acre (43,054 and 109,787 per ha), respectively (Esslinger and Klimstra 1983). Cultivation reduces the availability of spent shot to waterfowl by ≥80% (Fredrickson et al. 1977; Esslinger 1979).

Pheasant Put-and-take Hunting Area. Twenty-five spent shot were found in 52 samples collected during May 1983 in fields heavily used by Canada geese for feeding on the pheasant put-and-take hunting area adjacent to Rend Lake (Table 1). This rate is equivalent to 20,900 pellets per acre (51,643 per ha) or 1 pellet per 2.08 square feet (per 0.2 m^2) in the upper 1 inch (25.4 mm) of soil. Sixty-seven spent shot were found in 53 samples collected along woody fencerows and in a field of corn stubble favored by pheasant hunters, a rate equivalent to 55,100 pellets per acre (136,150 per ha).

All 92 pellets found in these samples were lead. Shot sizes were distributed as follows: No. 6 (44.6%); No. 7 ½, 8, and 9 (35.9%); No. 4 and 5 (18.4%); and No. 2 (1.1%).

Mourning Dove Hunting Area. The 100 soil samples collected from the dove hunting field in Sam Parr State Park in July 1979 contained 65 spent shot, a rate equivalent to about 28,300 shot per acre (69,928 per ha) in the upper ½ inch (12.7 mm) of soil. The south and north halves of the field averaged 33,100 and 25,500 pellets per acre (81,789 and 58,068 per ha), respectively (Table 1). In October, after 95% of the annual dove hunting was completed, 50 soil samples from the north half of the field yielded 84 spent shot, a rate equivalent to 73,200 pellets per acre (180,875 per ha), or an increase of 211% from July to October. Four of the 84 shot in the October samples were No. 4 steel, and these were attributed to hunters who had participated in a test of the effectiveness of nontoxic shot for hunting mourning doves (Kringer et al. 1980).

For purposes of comparison, we cite Lewis and Legler (1968), who reported a pre-hunt average of 10,980 pellets per acre (27,131 per ha) and a post-hunt average of 43,560 pellets per acre (107,635 per ha) in the upper ⅜ inch (9.5 mm) of soil in a dove field in Tennessee.

Ingested Shot

In this report, data for the incidence of ingested shot in mallards, lesser scaups, and Canada geese are summarized by collection site, navigation pool, lake, or county (Fig. 5). Most of these sites may be thought of as ecological "units." Appendix B provides this information by area and year of collection for these three species and for redheads and ring-necked ducks.

Incidence of Ingested Shot. The incidence of ingested shot in the 13,779 mallards sampled throughout the state in 1979–1985 averaged 5.9%. The incidence in mallards harvested along the upper Mississippi River during that period averaged 4.1% (Table 2). Rates were >5.0% for Pools 12, 16, and 25, and 1.1–4.3% for the other six navigation pools. The incidence of ingested shot in mallards harvested along the Illinois River averaged 7.6% and was >5.0% in all areas sampled. In northeastern Illinois, incidences averaged 3.4%, with a high of 5.0% occurring in McHenry County. Rates were 3.2–3.8% in Kane, Will, and Grundy counties. In central and southern Illinois, the incidence of ingested shot in mallards averaged 5.1%. Incidences were >5.0% for Oakwood Bottoms in Jackson County and for Horseshoe Lake in Madison County. Ingested shot occurred at rates of 2.4–4.3% on the other seven areas sampled (Table 2).

Table 1. Abundance of spent shotgun pellets in soil or sediment on three hunting areas in Illinois.

Vegetation and Use	Date	Size Acres (Ha)	Number of Samples	Pellets	
				Number	Per Acre (Ha)
Waterfowl Hunting Area (Casey Fork Subimpoundment at Rend Lake, Jefferson County)					
Unflooded corn, heavily hunted (goose firing line)	27 April–17 May 1982	41 (16.6)	65 [a]	55	36,900 (91,179)
Flooded and fallow, heavily hunted	27 April–17 May 1982	61 (24.7)	50 [b]	87	75,800 (187,299)
Flooded buckwheat and Japanese millet, moderately hunted	27 April–17 May 1982	73 (29.5)	50 [b]	19 [c]	16,600 (41,018)
Flooded milo, moderately hunted	27 April–17 May 1982	98 (39.7)	50 [b]	25	21,800 (53,867)
Pheasant Put-and-take Hunting Area (Wayne Fitzgerrell State Recreation Area at Rend Lake, Franklin County)					
Corn and milo stubble, heavily used	6-12 May 1983 by Canada geese	68 (27.5)	52 [a]	25	20,900 (51,643)
Woody fencerows (75%) and corn stubble (25%), heavily hunted	6–12 May 1983	53 (21.4)	53 [a]	67	55,100 (136,150)
Mourning Dove Hunting Area (Sam Parr State Park, Jasper County)					
Sunflowers growing in disked soil	5 July 1979	18 (7.3)	50 [d]	38	33,100 (81,789)
Sunflowers growing in disked soil	5 July 1979	17 (6.9) [f]	50 [d]	27	23,500 (58,068)
Mature sunflowers, heavily hunted	4 October 1979	17 (6.9) [f]	50 [d]	84	73,200 (180,875)

[a] Each sample was 12 inches square (30.5 cm^2) and 1 inch (2.5 cm) deep.
[b] Each sample was 12 inches square (30.5 cm^2) and 2 inches (5.1 cm) deep.
[c] One lead .22 rifle bullet was also found.
[d] Each sample was 12 inches square (30.5 cm^2) and 0.5 inch (1.3 cm) deep.
[e] South half of field.
[f] North half of field.

Table 2. Incidence of ingested shotgun pellets in mallards harvested in Illinois, 1979–1985 hunting seasons (see Appendix B for breakdown of the data by area and year).

Location	Number of Gizzards	Number of Gizzards with Pellets				% of Gizzards with Pellets
		Lead	Steel	Both	Total	
Upper Mississippi River						
Pool 12	96	2	1	2	5	5.2
Pool 13	1,196	37	12	3	52	4.3
Pool 16	295	15	0	0	15	5.1
Pool 17	283	4	0	0	4	1.4
Pool 18	280	6	1	0	7	2.5
Pool 21	140	2	1	0	3	2.1
Pool 22	95	0	1	0	1	1.1
Pool 24	535	9	2	0	11	2.1
Pool 25	576	41	5	1	47	8.2
Total	3,496	116	23	6	145	4.1
Illinois River						
Peoria Pool, upper	1,049	59	10	5	74	7.1
Peoria Pool, lower	1,177	50	21	4	75	6.4
La Grange Pool, upper	1,099	54	8	1	63	5.7
La Grange Pool, lower	1,641	158	21	4	183	11.2
Pool 26, upper [a]	156	8	2	0	10	6.4
Pool 26, lower [a]	1,093	54	9	3	66	6.0
Total	6,215	383	71	17	471	7.6
Northeastern Illinois						
McHenry County	80	4	0	0	4	5.0
Kane County	221	7	0	0	7	3.2
Cook County	18	0	0	0	0	—[b]
Will County	80	1	2	0	3	3.8
Grundy County	297	7	3	0	10	3.4
Total	696	19	5	0	24	3.4
Central and Southern Illinois						
Sangchris Lake	450	9	3	0	12	2.7
Shelbyville Lake	42	1	0	0	1	2.4
Carlyle Lake	372	13	1	0	14	3.8
Rend Lake	884	27	4	1	32	3.6
Kaskaskia River [c]	198	2	2	1	5	2.5
Mermet Lake	280	9	2	1	12	4.3
Oakwood Bottoms	208	10	6	1	17	8.2
Horseshoe Lake [d]	625	45	22	2	69	11.0
Monroe County	313	9	2	0	11	3.5
Total	3,372	125	42	6	173	5.1
All areas	13,779	643	141	29	813	5.9

[a] The portion of the Illinois River downstream from La Grange Pool was under the influence of Lock and Dam 26 on the Mississippi River.
[b] Not calculated because of small sample size.
[c] St. Clair and Randolph counties.
[d] Madison County.

The incidence of ingested shot in 1,385 lesser scaups harvested throughout Illinois during 1979–1985 averaged 6.9% (Table 3). The incidence was 3.6% for Pool 19 on the Mississippi River, a major resting and feeding area for migrating diving ducks. Other incidences included 5.7% for Heidecke Lake in Grundy County, 5.1% for Horseshoe Lake in Madison County, and 50.0% for Shelbyville Lake, where about 2,000 lesser scaups and 400 ring-necked ducks were attracted to Japanese millet grown abundantly in the Fish Hook Subimpoundment in 1984. Because lesser scaups fed on abundant seeds on firm sediment in shallow (<6 ft; 1.8 m) water , these birds incurred the highest ingestion rate in this study (die-offs notwithstanding).

The incidence of ingested shot in Canada geese harvested during 1981–1984 was 1.2, 6.5, and 6.9%, respectively, for Rend Lake in Franklin and Jefferson counties, Union County Refuge, and Horseshoe Lake Refuge in Alexander County (Table 4). For the 887 geese sampled, the incidence was 5.6%.

An historical comparison can be made with earlier data collected by Bellrose (1959:262–263). He reported an incidence of ingested shot in Illinois during 1938–1954 of 7.9% for 5,259 mallards and 11.5% for 451 lesser scaups. The incidence among 511 Canada geese harvested in North America during the same years was 0.8% (Bellrose 1959:260). A geographical comparison can be drawn with 10–22 states during 1977–1984. Incidence of ingested shot in those areas averaged 8.1% for 81,480 mallards, 12.5% for 5,723 lesser and greater scaups, and 4.6% for 12,201 Canada geese (Sanderson and Bellrose 1986: 4,7).

Ingestion of Multiple Shot. One pellet was found in 75.8% of 813 mallard gizzards containing ingested shot, 2 pellets were found in 13.6%, and 3–21 pellets in 10.6% (Table 5). Values for 95 lesser scaups were 1 pellet, 56.8%; 2 pellets, 21.1%; and 3–9 pellets, 22.1%. Fifty Canada geese had ingested shot at the following rates: 1 pellet, 86.0%; 2 pellets, 6.0%; and 3–6 pellets, 8.0%.

Table 3. Incidence of ingested shotgun pellets in lesser scaups harvested in Illinois, 1979–1985 hunting seasons (see Appendix B for breakdown of the data by year).

Location	Number of Gizzards	Number of Gizzards with Pellets				% of Gizzards with Pellets
		Lead	Steel	Both	Total	
Mississippi River						
Pool 16	19	0	0	0	0	—[a]
Pool 18	12	0	0	0	0	—
Pool 19	977	23	10	2	35	3.6
Lake Michigan	24	2	0	0	2	—
Calumet Lake	4	0	0	0	0	—
Heidecke Lake	122	4	2	1	7	5.7
Shelbyville Lake	90[b]	40	1	4	45	50.0
Horseshoe Lake[c]	137	7	0	0	7	5.1
All areas	1,385	76	13	7	96	6.9

[a] Not calculated because of small sample size.
[b] From Fish Hook Subimpoundment.
[c] Madison County.

Table 4. Incidence of ingested shotgun pellets in Canada geese harvested in Illinois, 1981–1984 hunting seasons (see Appendix B for breakdown of the data by year).

Location	Number of Gizzards	Number of Gizzards with Pellets				% of Gizzards with Pellets
		Lead	Steel	Both	Total	
Rend Lake	170	2	0	0	2	1.2
Union County Refuge	338	10	11	1	22	6.5
Horseshoe Lake Refuge[a]	379	26	0	0	26	6.9
All areas	887	38	11	1	50	5.6

[a] Alexander County.

A comparison can be made with data collected by Bellrose (1959:260) thirty years earlier. He found the following rates among 1,159 mallards with ingested shot that had been collected in the United States and Canada during 1938–1954: 1 pellet, 65.3%; 2 pellets, 16.7%; and ≥3 pellets, 18.6%. His values for lesser scaups were 1 pellet, 57.8%; 2 pellets, 16.3%; and ≥3 pellets, 15.9%. More recently (1974–1980), 63.0% of 1,211 mallard gizzards collected in several states contained 1 pellet, 13.6% had 2 pellets, and 23.4% had ≥3 pellets (Sanderson and Bellrose 1986:6).

Presence of Nontoxic Shot. Of the 813 mallard gizzards with ingested shot that were collected in Illinois during 1979–1985, 20.9% contained ≥1 nontoxic (steel) pellet (Table 6). Values for mallards along the upper Mississippi River were 20.0%; along the Illinois River, 18.9%; in northeastern Illinois, 20.8%; and in central and southern Illinois, 27.7%. One or more nontoxic pellets were found in 20.8% of 96 lesser scaup gizzards that contained ingested shot and in 24.0% of 50 Canada goose gizzards with ingested shot (Table 6).

On areas where nontoxic shot was used extensively for waterfowl hunting (required by law or used voluntarily), 46.2% of the mallards with ingested shot had ≥1 nontoxic pellet; on areas where lead shot was used, this value was 17.7% (Table 6). For Canada geese, the values averaged 25.0% on steel shot areas and 0.0% on lead shot areas.

Shot-in Pellets

Shot-in pellets—those penetrating the lumen—were found in 5.8% of 13,779 mallard gizzards collected in Illinois during the 1979–1985 hunting seasons, in 3.2% of the gizzards of 1,385 lesser scaups, and in 4.8% of the gizzards of 887 Canada geese. These percentages are of sufficient magnitude to influence the interpretation of data for ingested shot if shot-in pellets are not properly identified. For example, incorrect indentification of one-half of the shot-in pellets would inflate the reported incidence of ingested shot by ≥100% in all mallard populations in which the actual incidence was ≤3% (Table 2).

Of the 793 mallard gizzards with shot-in pellets, 90.3% contained lead and 9.7% contained steel. Values for the 45 lesser scaup gizzards with shot-in pellets were 75.6% lead and 24.4% steel; for the 43 Canada geese, 65.1% lead and 34.9% steel.

Blood and Liver Chemistry

An average of 17.3% of the blood samples collected from 1,135 mallards on four areas in Illinois during 1980–1983 had concentrations of lead that were above background levels. An average of 3.9% had concentrations of protoporphyrin that were above background (Table 7). Concentrations of lead above background levels occurred in 20.1% of blood samples from 264 canvasbacks on a single area, and concentrations of protoporphyrin above background levels occurred in 3.8% of the samples. Concentrations of lead above background levels were present in 24.3% of the blood samples collected from 864 Canada geese on three areas, and 3.1% of 857 of these samples had above-background concentrations of protoporphyrin. According to the arcsine test (Sokal and Rohlf 1969:607), differences between blood lead and protoporphyrin were significant ($P<0.05$) for each of the three species, with incidences of above-background

Table 5. Incidence of various numbers of ingested shotgun pellets in mallards, lesser scaups, and Canada geese harvested in Illinois, 1979–1985 hunting seasons.

Species	Number of Gizzards with Ingested Pellets	1 Pellet		2 Pellets		3 Pellets		4 Pellets		5 Pellets	
		No.	%	No.	%	No.	%	No.	%	No.	%
Mallards	813	616	75.8	111	13.6	39	4.8	17	2.1	10	1.2
Lesser scaups	95	54	56.8	20	21.1	6	6.3	6	6.3	2	2.1
Canada geese	50	43	86.0	3	6.0	1	2.0	2	4.0	0	0.0

Species	6 Pellets		7 Pellets		8 Pellets		9 Pellets		10 Pellets		> 10 Pellets	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Mallards	3	0.4	5	0.6	3	0.4	0	0.0	1	0.1	8[a]	1.0
Lesser scaups	3	3.2	0	0.0	2	2.1	2	2.1	0	0.0	0	0.0
Canada geese	1	2.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

[a] Included one gizzard with 11 pellets, three with 12 pellets, two with 13 pellets, one with 16 pellets, and one with 21 pellets.

concentrations of lead 4–8 times higher. Roscoe et al. (1979) reported that concentrations of lead in mallard blood peak more rapidly and remain elevated longer than do concentrations of protoporphyrin.

Gizzards collected from birds on the same areas as those occupied by the birds used for blood samples contained ingested lead pellets at average rates of 2.7% for mallards, 2.0% for lesser scaups (canvasbacks were not hunted), and 4.4% for Canada geese (Table 7). These percentages did not differ significantly ($P>0.05$) from the incidences of above-background concentrations of protoporphyrin in blood for the respective species. The averages of the incidences of ingested pellets, however, were significantly ($P<0.05$) lower than the averages of the incidences of above-background concentrations of blood lead: mallards, 17.3%; canvasbacks, 20.1%; and Canada geese, 24.3%.

Each of the three parameters (blood lead, protoporphyrin, and ingested pellets) indicates that Canada geese at Horseshoe Lake in Alexander County had a high rate (≥5.0%) of lead poisoning (Table 7). That is, blood chemistry results confirmed the high rate of lead poisoning indicated by the incidence of ingested pellets. In addition, blood-lead levels indicated that lead poisoning was extensive (≥5.0%) among mallards, canvasbacks, and Canada geese on all areas studied. The high rate of lead ingestion by mallards at Batchtown (4.3%) was also confirmed by the incidence of above-background concentrations of protoporphyrin (Table 7).

Livers from 6.9% of 335 mallards harvested on three areas in Illinois in 1985 had concentrations of lead above background levels (Table 8). Gizzards from the same 335 birds contained ingested lead pellets at an average rate of 5.7%. Differences between incidences of above-background concentrations of lead in the livers and incidences of ingested lead pellets in the gizzards were not significant ($P>0.05$). Concentrations of lead in livers disclosed that lead poisoning was pervasive on the three areas studied.

Lead Poisoning Die-offs

Information on documented instances of waterfowl die-offs in Illinois associated with lead poisoning is given in this section.

Table 6. Incidence of ingested shot and percentage that was lead and steel in mallards, lesser scaups, and Canada geese harvested on areas in Illinois where nontoxic shot (required by law or used voluntarily) or toxic lead shot was used, 1979–1985 hunting seasons.

Location	Hunting Seasons	Number of Gizzards	Gizzards with Ingested Shot			
			No.	%	% with Lead [a]	% with Steel [a]
Mallards						
Nontoxic shot required or used extensively						
Mallard Farms Duck Club	1979–1980	482	27	5.2	51.9	55.6
Rice Lake (public hunting area)	1979–1982	165	6	3.6	83.3	16.7
Stump Lake (public hunting area)	1979–1980	181	9	5.0	77.8	33.3
Nichols Duck Club	1981–1983	405	32	7.9	50.0	50.0
Oakwood Bottoms (public hunting area)	1980–1981	208	17	8.2	64.7	41.2
Total		1,441	91	6.3	58.2	46.2
Lead shot areas	1979–1985	12,338	722	5.9	85.7	17.7
All areas	1979–1985	13,779	813	5.9	82.7	20.9
Lesser Scaups						
Lead shot areas [b]	1979–1985	1,385	96	6.9	92.7	20.8
Canada Geese						
Nontoxic shot required						
Union County (public hunting area)	1982, 1984	338	22	6.5	45.5	54.5
Horseshoe Lake (public hunting area) [c]	1982, 1984	379	26	6.9	100	0.0
Total		717	48	6.7	77.1	25.0
Lead shot areas	1981–1983	170	2	1.2	100	0.0
All areas	1981–1984	887	50	5.6	78.0	24.0

[a] Some gizzards contained both lead and steel shot.

[b] All gizzards from lesser scaups were collected from areas outside nontoxic shot zones.

[c] Alexander County.

Horseshoe Lake and Union County Refuges and Crab Orchard National Wildlife Refuge, 1977. Personnel from the Illinois Department of Conservation observed Canada geese dying on Horseshoe Lake (Alexander County) and Union County refuges on 15 January 1977 (Fig. 8). The number of dead and sick geese continued to increase through 3 February. Refuge personnel picked up and buried 965 carcasses (266 at Horseshoe Lake, 519 at Union County, and 180 at Crab Orchard). Numerous additional carcasses could not be retrieved because they were offshore on thin ice. The die-off subsided by 23 February, following a moderation of the severe winter weather (low temperatures and deep snow) that had prevailed for several weeks. Stephen M. Kerr, U.S. Fish and Wildlife Service, estimated that 3,400–3,500 Canada geese had died, with most of the losses on Horseshoe Lake and Union County refuges. Estimates of total numbers of Canada geese were 85,000 at Horseshoe Lake, 54,000 at Union County, and 80,500 at Crab Orchard on 12 January 1977.

Twenty sick or dead Canada geese collected from these refuges were shipped to the National Wildlife Health Laboratory on 6 February; 18 were diagnosed as lead poisoned, 1 died of gunshot wounds, and 1 died from unknown causes. All tests for other diseases were negative. An additional 78 specimens were collected and examined by personnel from the U.S. Fish and Wildlife Service on 9 and 10 February: 63 (80.7%) were lead poisoned, 2 (2.6%) had impaction, 1 (1.3%) had streptococcal salpingitis, 1 had aspergillosis, 1 had myocardial infarction, 1 had gunshot wounds, and 9 (11.5%) had died from unknown causes. Of 75 gizzards examined, 54 (72.0%) contained 1–3 well-worn lead shot. Three other geese were collected on 24 February: 1 was lead poisoned, 1 had gunshot wounds, and 1 had died from unknown causes. Of the 82 geese that were diagnosed as lead poisoned, 40 (48.8%) were from Horseshoe Lake Refuge, 40 (48.8%) were from Union County Refuge, and 2 (2.4%) were from Crab Orchard National Wildlife Refuge.

Horseshoe Lake and Union County Refuges and Crab Orchard National Wildlife Refuge, 1978. According to Esslinger (1979), 170 dead Canada geese were collected at Horseshoe Lake Refuge (49 birds), Union

Table 7. Incidence of above-background concentrations of lead and protoporphyrin (PP) in blood of live-trapped waterfowl and incidence of ingested shotgun pellets in waterfowl harvested on selected areas in Illinois, 1980–1983.

Location	Fall-Winter Period	Wet Blood: % with ≥0.20 ppm Lead	Wet Blood: % with ≥40 mg/dl PP	Gizzards: % with Ingested Lead Pellets
Mallards				
Sangchris Lake (public hunting area)	1981–1982	23.5 (328)[a]	1.2 (328)	1.0 (98)
Kaskaskia River (public hunting area)	1981–1982	7.2 (307)	1.6 (307)	1.7 (173)
Batchtown (public hunting area)	1981–1982	23.2 (285)	9.8 (287)	4.3 (161)
Rend Lake (public hunting area)	1982–1983	12.1 (215)	3.3 (214)	2.9 (243)
Average		17.3 (1,135)	3.9 (1,136)	2.7 (675)
Canvasbacks				
Mississippi River, Pool 19	1980–1981	20.1 (264)[b]	3.8 (264)[b]	2.0 (51)[c]
Canada Geese				
Horseshoe Lake (public hunting area)[d]	1981–1982	53.2 (301)	5.6 (301)	8.1 (172)[e]
Union County (public hunting area)	1982–1983	14.7 (224)	1.4 (221)	2.2 (184)
Rend Lake (public hunting area)	1982–1983	5.0 (339)	2.1 (335)	1.4 (73)
Average		24.3 (864)	3.1 (857)	4.4 (429)

[a] Sample size.
[b] March 1981.
[c] Lesser scaups. Canvasbacks were not hunted on Pool 19.
[d] Alexander County.
[e] 1982–1983.

County Refuge (95 birds), and Crab Orchard National Wildlife Refuge (26 birds) from 24 January to 25 February 1978 (Fig. 8). The die-off occurred during a period of heavy snowfall. Gizzards from 164 of the geese were examined and 101 (62.2%) contained ingested lead shot. The incidence of ingested shot was 63.3% for Horseshoe Lake, 69.7% for Union County, and 34.6% for Crab Orchard. Ninety-five (58.3%) of the livers from 163 of these geese tested positive for lead poisoning. In a letter dated 24 April 1979, Ronald M. Windingstad, U.S. Fish and Wildlife Service, noted that an estimated 500 Canada geese had died of lead poisoning in southern Illinois during January and February 1978. Aerial censuses on 23 January 1978 indicated that 100,000 Canada geese were present at Horseshoe Lake, 90,000 at Union County, and 50,000 at Crab Orchard.

Horseshoe Lake and Union County Refuges, 1979. From 19 January to 16 February 1979, 128 and 420 Canada goose carcasses were collected at Horseshoe Lake and Union County refuges (Fig. 8), respectively (Esslinger 1979). Examination of 515 gizzards from these geese disclosed that 71 (13.8%) contained ingested lead shot. Of 150 livers analyzed, 68 (45.3%) tested positive for lead poisoning. Ronald M. Windingstad of the U.S. Fish and Wildlife Service estimated that 200 Canada geese had died of lead poisoning and 800 of avian cholera in southern Illinois during January and February 1979 (letter dated 24 April 1979). The lead-induced losses were more characteristic of chronic lead poisoning than of the dramatic die-offs that had occurred in previous years. Censuses on 22 January 1979 reported 18,000 Canada geese at Horseshoe Lake, 25,000 at Union County, and 3,000 at Crab Orchard.

Quiver Creek, 1980. The Illinois Natural History Survey was informed on 22 March 1980 that ducks were dying along Quiver Creek near Topeka in Mason County (Fig. 8). Robert D. Crompton, Stephen P. Havera, and H. Kathleen Belcher of the Survey visited the area on 24–28 March and found 147 dead ducks (20 mallards, 6 black ducks, 9 pintails, 11 wigeons, 4 gadwalls, 16 shovelers, 15 blue-winged teals, 9 green-winged teals, 4 wood ducks, 24 ring-necked ducks, 1 redhead, and 28 lesser scaups) and 8 sick birds (5 lesser scaups and 3 coots). Gizzards from 57 of the dead birds were examined, and 46 (80.7%) were found to contain from 1 to 33 lead pellets each. Specifically, 9 duck gizzards contained 1 pellet each; 26 duck gizzards contained 2–5 pellets each, and 11 duck gizzards contained ≥6 pellets each. Necropsy of 10 birds from the Quiver Creek die-off (9 ring-necked ducks and 1 redhead) by the National Wildlife Health Laboratory failed to isolate lead poisoning, or any other agent, as the cause of death. Livers (wet weight) from the birds contained only 0.5 to 1.4 ppm of lead. Body weights, which were normal to slightly lower than normal, suggested that the birds had died quickly. Aerial censuses on 18 March 1980 reported 88,450 ducks on Quiver Creek and 64,475 on the adjacent Chautauqua National Wildlife Refuge.

Although lead was associated with this die-off (i.e., gizzards of 80.7% of a sample of 57 birds contained ingested lead pellets), lead poisoning was not unequivocally indentified as the lethal agent. An unidentified pathogen may have worked in combination with lead to induce rapid death. In this regard, spring botulism, which can be diagnosed only with fresh serum from live birds, is a highly probable cause. Total losses were estimated by Crompton to be 220 birds.

Quiver Creek, 1985 and 1988. Shortly after the close of the 1985 waterfowl season, Robert D. Crompton of the Survey conducted a search on foot for sick, dead, and crippled ducks along Quiver Creek in Mason County (Fig. 8), where nontoxic (steel) shot was required for waterfowl hunting. From 7 December 1985 through 5 January 1986, Crompton picked up 48

Table 8. Incidence of above-background concentrations of lead in livers and incidence of ingested lead shotgun pellets in mallards harvested on selected areas in Illinois, 1985 hunting season.

Location	Fall Period	Wet Livers[a] % with ≥ 2.0 ppm Lead	Gizzards[a] % with Ingested Lead Pellets
Potter's Marsh (public hunting area)	1985	8.0 (87)[b]	6.9 (87)
Woodford County (public hunting area)	1985	6.7 (150)	2.7 (150)
Stump Lake (public hunting area)	1985	6.1 (98)	9.2 (98)
Average		6.9 (335)	5.7 (335)

[a] Paired liver-gizzard samples from the same birds.
[b] Sample sizes.

ducks. Severe winter weather and snow cover prevailed during this period. Inspection of the gizzards of these birds revealed that 36 had ingested lead shot. The remaining 12 were cripples with broken wings or other disabling shot injuries. This 3:1 ratio indicates that for 30 days following the 1985 hunting season lead poisoning was more detrimental to waterfowl on this area than was crippling. The 36 birds with ingested shot included 30 mallards, 5 wigeons, and 1 pintail; among the 12 crippled birds were 7 mallards, 2 wood ducks, and 3 goldeneyes.

Following the close of the 1987 hunting season on 30 November, the third consecutive season for which nontoxic shot was required for hunting waterfowl in the Quiver Creek area, Crompton conducted another search on foot along the creek. He collected 64 ducks and Canada geese from 2 January through 10 February 1988. Inspection of the gizzards of these birds revealed that 48 had ingested lead shot; the remaining 16 were cripples with broken wings. Once again, the ratio was 3:1, even after three years of mandatory nontoxic shot regulations. Apparently either lead pellets from previous years remained available to birds in the Quiver Creek area or not all hunters had complied with the nontoxic shot regulations. The 48 birds that had ingested shot included 37 mallards, 5 wood ducks, 3 wigeons, and 3 Canada geese. The 16 crippled birds were mallards.

Horseshoe Lake, 1981. The die-off at Horseshoe Lake in Madison County (Fig. 8) occurred during February 1981 when about 3,000 ducks (2,500 canvasbacks, 400 common goldeneyes, and 100 birds representing a variety of species) concentrated in open areas at this otherwise ice-bound body of water. About 20 acres (8.1 ha) of open water 50–60 feet (15.2–18.3 m) deep surrounded a sand and gravel dredge. An additional 15 acres (6.1 ha) of open water had depths of only 4–5 feet (1.2–1.5 m). Large numbers of winter-killed gizzard shad, an attractive source of food for ducks, were present in the open water.

William F. Nichols, a local resident, noticed sick birds one or two days after ducks arrived at the lake. He observed that sick birds crawled onto the edge of the ice at a rate of 10–25 per day for a period of three weeks. However, an accumulation of carcasses did not result because, as Nichols eventually determined, the victims were scavanged soon after they appeared on the ice. To quote Nichols (letter in *Illinois Wildlife*, 22 April 1981), "The mystery was solved when I saw a dying bird attacked by three gulls and the carcass entirely stripped clean of all flesh in a 2½-hour period. A pile of feathers and the bones were all that remained, and in most cases the remains were dragged into the water and sank from sight and all evidence of the death was removed in a natural process."

Four of the dead ducks were submitted to the National Wildlife Health Laboratory; of these, 1 canvasback and 1 goldeneye were diagnosed as lead poisoned. These birds had 17.8 and 31.6 ppm of lead in their livers (wet weight), respectively. The other 2 ducks (goldeneye and ruddy duck) contained only 1.9 and 1.0 ppm of lead in their livers, respectively. The goldeneye had a broken neck, and the cause of death of the ruddy duck was undetermined. Nichols estimated that 400–500 ducks, primarily canvasbacks, were lost during this die-off.

Rend Lake, 1981. The Illinois Department of Conservation was notified on 2 March 1981 that Canada geese were dying at Rend Lake in Franklin and Jefferson counties (Fig. 8). Dennis D. Thornburg and Timothy Sickmeyer of the Department walked shorelines on 4 March and searched via helicopter on 10 March and found 115 dead birds (110 geese and 5 mallards) and 21 sick birds (5 geese and 16 mallards). Most victims were found along the west side of Casey Fork Subimpoundment, where several thousand birds had been feeding in shallow water. Composite samples

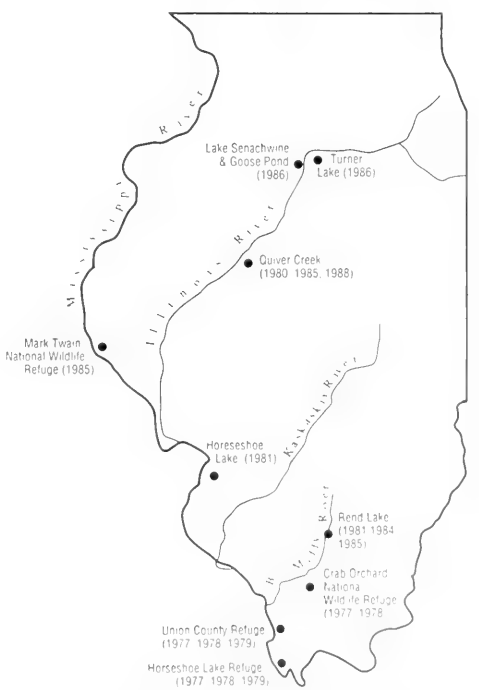

FIGURE 8. Areas in which waterfowl die-offs attributed to lead poisoning occurred. The year of the die-off is given in parentheses.

representing 5 geese contained 6.3 and 11.5 ppm of lead in liver and gizzard contents (wet weight), respectively, as determined by the Illinois Department of Agriculture Diagnostic Laboratory. Concentrations of lead in livers from 3 additional birds sent to the National Wildlife Health Laboratory were 11.7 ppm (goose), 19.6 ppm (goose), and 19.0 ppm (mallard). Thornburg estimated losses during this die-off of 450 to 600 birds (350–450 Canada geese and 100–150 mallards). The die-off was associated with severe winter weather. An aerial census revealed that 75,000 Canada geese had been using Rend Lake on 13 February 1981.

Rend Lake, 1984. Searches made by Bill Mestel and Harold Atchison of the Illinois Department of Conservation at Rend Lake (Fig. 8) on 4–11 January and 10 February 1984 produced 67 dead waterfowl (50 Canada geese, 16 mallards, and 1 black duck) and 23 sick waterfowl (18 Canada geese and 5 mallards). Most of the dead and sick birds were found at two open-water sites (the lake was frozen) in the refuge, where large numbers of waterfowl had concentrated. On 9 January 1984, approximately 34,000 Canada geese had been present at Rend Lake.

Carcasses of 32 of the dead birds (25 Canada geese, 6 mallards, and 1 black duck) were necropsied at Southern Illinois University, Carbondale (31 birds), or at the National Wildlife Health Laboratory (1 bird). Causes of death for 28 of the waterfowl (23 Canada geese, 4 mallards, and 1 black duck) were determined: 16 (13 Canada geese, 2 mallards, and 1 black duck) (57%) died of trauma caused by gunshot wounds, 1 (Canada goose) (4%) died of enteritis, 6 (5 Canada geese and 1 mallard) (21%) died of lead poisoning, and 5 (4 Canada geese and 1 mallard) (18%) were suspected lead poisoning deaths.

The 6 waterfowl that died from lead poisoning had high (>6.0 ppm wet weight) concentrations of lead in their livers and exhibited visible symptoms of the disease. Three of these birds also had ingested lead shot in their gizzards. One of the 5 waterfowl that probably died of lead poisoning had 4.93 ppm of lead in its liver; the remaining 4 exhibited symptoms of the disease, and 2 of these also had ingested lead shot in their gizzards.

Lead poisoning was also implicated in the deaths of two of the trauma victims: a mallard with 5.71 ppm of lead in its liver and a Canada goose with 2 ingested lead shot in its gizzard. Thus, lead poisoning was associated with 13 (46%) of the 28 waterfowl for which the cause of death was determined.

Rend Lake, 1985. Bill Mestel and Harold Atchison of the Illinois Department of Conservation searched for dead and sick waterfowl at Rend Lake on 1–19 February 1985 (Fig. 8). The specific location was the west side of the lake near the Turnip Patch Access in the vicinity of the Jefferson County–Franklin County line. This portion of the lake had received heavy gunning pressure during the 1984 hunting season. Forty-five birds (40 Canada geese, 4 mallards, and 1 wood duck) were picked up and placed in cold storage. The birds were difficult to find because recent snows had covered the area. Most of the birds, which were concentrated near open water in the otherwise frozen lake, were dead when discovered; the few that were alive died soon afterwards. The Canada goose population on the area was estimated at 42,000 on 4 February 1985.

All of the collected birds, except one badly deteriorated goose, were sent to the National Wildlife Health Laboratory. In a letter dated 9 May 1985, Ronald M. Windingstad reported on the necropsies.

> The 44 waterfowl carcasses (Case No. 5474) from Rend Lake you submitted on March 22 have been necropsied and final diagnoses made. Lead poisoning was the primary cause of death in 25 of the 39 Canada geese and in three of the four mallards. Lead was a secondary factor in two other geese. Aspergillosis and avian tuberculosis were diagnosed in two geese and two cases of visceral gout were seen. Four geese were victims of trauma and no diagnosis was reached in five goose carcasses. One mallard and the wood duck submitted also remain open (no diagnosis). Lead poisoning was ruled out for those carcasses that have an open diagnosis.
>
> Both the Canada geese and mallards diagnosed as lead poisoning were classic examples in that they were emaciated, the livers were atrophied, gall bladders were engorged with bile, gizzard linings were bile stained, and heart muscles were flaccid. Gizzard and proventricular impaction was noted in some of the Canada geese as well. Worn lead shot was recovered from 16 of the geese suffering from lead poisoning and from 2 of the 3 mallards diagnosed as lead. Nine geese had one shot each recovered, two had two, one had three, one had four, one had five, and two had six shot each. Both mallards having shot had one each.

Delair Division, Mark Twain National Wildlife Refuge, 1985. The caretaker of a private hunting club located adjacent to the Mark Twain National Wildlife Refuge in Pike County (Fig. 8) noticed Canada geese that could not fly on 3 February 1985. Several clubs were leased in this area and all had been heavily hunted. The geese appeared to have normal weights and held their heads upright; they could walk and swim but could not fly. These birds were part of a flock of about 1,000 Canada geese that had been using 1 acre (0.4 ha) of open water seepage in a 15-acre (6.1-ha) frozen basin. Weather during the three preceding weeks had been cold (–10 to 27°F, –23.3 to –2.8°C) with 3–4 inches (7.6–10.2 cm) of snow cover.

Personnel from the U.S. Fish and Wildlife Service inspected the area on 6 February and found 10 dead or sick Canada geese. They collected 5 geese (2 dead and 3 sick) and shipped them to the National Wildlife Health Laboratory, where all 5 birds were diagnosed as victims of lead poisoning. Each had ≥1 ingested lead pellets in its gizzard and >8.0 ppm of lead in its liver (wet weight). In a memorandum dated 15 February 1985, Dr. Louis N. Locke of the Laboratory summarized the results of the necropsies:

> Although all five geese were in rather good condition (well-developed breast muscles and good deposits of fat), the lead damage to the heart (definitely present in four of the five, suspected in the fifth goose) appears to have been the major lesion responsible for their deaths.

During the winter of 1985–1986, 6 additional dead or sick Canada geese were found in the same area. Two birds were collected and 1 of them was necropsied by refuge personnel. The necropsied bird had 4 ingested lead pellets in its gizzard and exhibited symptoms of lead poisoning.

Lake Senachwine–Goose Pond, 1986. On 22 February 1986, Canada geese were discovered dying on the grounds of private hunting clubs on the west side of Lake Senachwine and Goose Pond (Sections 7, 8, 17, and 18, Senachwine Twp., Putnam Co.) (Fig. 8). Max Runkle of the Illinois Department of Conservation inspected the area on 24 February and made several additional searches through 17 March. At least 7,000 Canada geese were in the vicinity on 4 March and thereafter. Runkle observed a maximum of 30 geese in distress at any given time and found a total of 61 dead birds (57 Canada geese, 3 mallards, and 1 black duck). Fifteen of these geese were sent to the National Wildlife Health Laboratory, and all were diagnosed as having died from lead poisoning. One of the birds also had "necrotic enteritis of geese," but tests for all other diseases were negative. Gizzards from 14 of the necropsied geese were examined, and 12 of these (85.7%) contained 2–49 lead shot. The average was 13.2 pellets per bird. Livers from the 15 necropsied geese contained 6.4–40.1 ppm (average 17.2 ppm) of lead on a wet-weight basis. Six additional geese were examined in the field, and 5 of these contained ingested shot in their gizzards.

Turner Lake, 1986. Sick lesser scaups were first noticed on the grounds of private hunting clubs on Turner Lake in Putnam County on 30 March 1986 (Fig. 8). Michael Resetich of the Illinois Department of Conservation maintained surveillance of the area through 21 April, during which time he picked up 37 scaups in advanced stages of distress. One bird was dead, 18 others died soon after capture, and the remaining 18 birds were released. During the die-off, 5,500–6,000 ducks (50% lesser scaups) were present on the lake. Seven of the scaups collected by Resetich were necropsied at the National Wildlife Health Laboratory, and all were diagnosed as victims of lead poisoning: each had 2–6 lead shot (average 3.9 shot) in its gizzard and 34.0–71.4 ppm (average 53.5 ppm) of lead in its liver on a wet-weight basis. All tests for other diseases were negative. The Diagnostic Services Case Report reads,

> All birds had *very* elevated liver lead values and evidence of ingested shot. The shot ranged from well worn to freshly ingested and the birds' conditions ranged from fat to emaciated indicating the toxicosis probably has occurred on a continuing basis from ingestion of shot at or near the site from which they were collected [emphasis in original].

Two additional scaups were examined in the field; one had 1 lead shot in its gizzard, the other had 4.

The area had produced an excellent crop of food during the growing season of 1985, much of which lasted throughout the winter and attracted scaups and other waterfowl to the area during the spring migration. Water depths were apparently sufficient to prevent dabbling ducks from feeding on the bottom, and scaups appeared to be the only species that ingested enough lead shot to be affected. This die-off had characteristics similar to the much larger one that occurred at Rice Lake in the spring of 1972 (Anderson 1975).

Nontoxic Shot Regulations

More than a decade of legislative efforts, lobbying, and legal controversy accompanied the development and implementation of nontoxic shot regulations. Much is to be learned about the biopolitics of wildlife conservation by looking back over that period.

Legislation

Nontoxic shot regulations in Illinois have been, and will be, influenced by the Migratory Bird Treaty Act, the Endangered Species Act, and two recent pieces of legislation. Between 1978 and 1985, the U.S. Fish and Wildlife Service refrained from requiring nontoxic shot zones in states that did not request or consent to such zones. In part, this policy arose from a restriction contained in the U.S. Department of the Interior Appropriations Act that began 1 October 1978. This legislation, frequently referred to as the Stevens Amendment, forestalled the Fish and Wildlife Service from implementing or enforcing nontoxic shot zones without the consent of the appropriate state authority:

> No funds appropriated by this Act shall be available for the implementation or enforcement of any rule or regulation of the United States Fish and Wildlife Service

> Department of the Interior, requiring the use of steel shot in connection with the hunting of waterfowl in any State of the United States unless the appropriate State regulatory authority approves such implementation.

The Stevens Amendment in combination with policies of the Fish and Wildlife Service effectively delegated authority for nontoxic shot regulations to the individual states, which as isolated entities were vulnerable to political pressures and lobbying efforts. As a result, many states discontinued or severely curtailed their nontoxic shot regulations prior to the 1978 or 1979 hunting season. The Stevens Amendment was reenacted by Congress for every subsequent fiscal year until 22 December 1987, at which time it expired and was not reenacted when Congress enacted the Department of the Interior appropriations bill for fiscal year 1988.

In addition, Statute 2.18-1 of the Illinois Conservation Laws severely restricted the latitude of the Department of Conservation in establishing nontoxic shot zones beginning in 1979:

> It shall be lawful for any person who holds the licenses, permits and stamps required by this Act for the taking of migratory waterfowl to use, in addition to or in lieu of any other authorized ammunition, either lead or steel shotgun pellets in taking such waterfowl at any location in the State where the hunting of migratory waterfowl is authorized, except at specific sites where there are documented cases of lead poisoning of waterfowl and all alternative methods of alleviating lead poisoning (such as dewatering, flooding and/or tillage) have been determined to be unsuccessful in preventing lead poisoning losses of waterfowl. At such specific sites, shot shell ammunition containing non-toxic pellets, such as steel, shall be used. These specific sites may be designated by the Department after statewide public hearings have been conducted and the results of such hearings have been reviewed.

The phrase "documented cases of lead poisoning in waterfowl" was interpreted by legal consultants for the Department of Conservation as cases in which waterfowl *had died* and were determined through necropsy to have been victims of lead poisoning. The legal consultants interpreted "specific sites" in terms of the boundaries of any property, but in practice these sites were limited to public hunting areas. Because of the Illinois statute and the ramifications of the Stevens Amendment, the Department of Conservation was forced to ignore day-to-day losses of waterfowl to lead poisoning. Nontoxic shot zones atuned to ecological units could not be established, and the Department had to delay action to accommodate the provisions for "alternative methods" and "public hearings." In short, Statute 2.18-1 prevented the Department of Conservation from effectively addressing the problem of lead poisoning in waterfowl.

The Endangered Species Act came into play as evidence increased that the endangered bald eagle was ingesting spent lead shot embedded in or ingested by its waterfowl prey or carrion. The Fish and Wildlife Service was subjected to pressure from conservation organizations to restrict the use of lead shot in areas frequented by wintering bald eagles. In 1985, the Fish and Wildlife Service proposed nontoxic shot zones in all or parts of 30 counties in eight states (including Illinois) for the protection of bald eagles. Only three of these states consented to the proposed zones, however, and the Fish and Wildlife Service decided to allow the use of lead shot in the remaining five states (including Illinois). At the same time, the Fish and Wildlife Service announced that it would exercise its authority under the Migratory Bird Treaty Act and not open the 1986–1987 waterfowl hunting season in the 22 excluded counties if the affected states did not consent to nontoxic shot zones (*Federal Register* 50:19,248, 7 May 1985). The exclusion of 22 counties or portions thereof from the bald eagle proposal and the announcement of the closed season policy set the stage for lawsuits brought by the National Wildlife Federation (discussed in the following section).

In 1987, in response to a decision by the Fish and Wildlife Service not to open certain areas in Illinois to waterfowl hunting unless nontoxic shot regulations were approved (*Federal Register* 52:1,638, 15 January 1987), Statute 2.18-1 was amended:

> The Department shall be authorized to designate, by rule, pursuant to the Administrative Procedure Act, areas that shall be limited to the use of non-toxic pellets; provided however, that such authorization shall only exist for those areas which the federal government has mandated shall be closed to all waterfowl hunting unless the State agrees to the prohibition of the use of toxic shotgun pellets.

Had this amendment not been made, the statute would have prevented the Department of Conservation from approving the nontoxic shot zones proposed for 1987 (there were no "documented cases of lead poisoning in waterfowl" in the areas in question), and the Fish and Wildlife Service would not have opened the areas to waterfowl hunting. The amendment was signed into law on 30 July 1987, the Department of Conservation gave the Fish and Wildlife Service approval to establish the nontoxic shot zones on 31 July, and descriptions of the zones were printed in the *Federal Register* on 25 August.

According to a survey following the 1985 season, a majority (62.1%) of Illinois hunters disliked steel shot but would use it rather than have their areas closed to waterfowl hunting (Table 9). An additional 27.0% favored or had no objections to steel shot and would use it if required by law. Only 7.3% of the respondents

strongly opposed the use of steel shot and would rather have their areas closed to waterfowl hunting than use it. In brief, Illinois waterfowl hunters overwhelmingly supported continuation of their sport regardless of nontoxic shot regulations.

Lawsuits

Five of the eight court cases involving the implementation of nontoxic shot regulations to protect waterfowl or bald eagles from lead poisoning were held in federal district courts (one in Washington, D.C., one in northern New York, and three in eastern California); the remaining three were in state courts (South Dakota, Texas, and Florida). The first five cases (two federal and three state) were initiated by the National Rifle Association of America or by local sportsmen from 1976 to 1981. Plaintiffs argued unsuccessfully that regulations requiring the use of nontoxic shot were arbitrary and capricious, that steel shot was ballistically inferior to lead shot and damaged firearms, and that losses from lead poisoning were insufficient to warrant the use of nontoxic shot (Feierabend 1985). Three of the decisions were also appealed unsuccessfully.

In 1985, the National Wildlife Federation sued the U.S. Department of the Interior in an effort to prohibit the use of lead shot for waterfowl hunting in 15 counties and portions of 7 others in five states (10 counties in Illinois). These were the same areas that the Fish and Wildlife Service had proposed as nontoxic shot zones for the protection of bald eagles in states that refused to consent to the zones proposed earlier. The lawsuit, filed in the U.S. District Court for the Eastern District of California, sought protection for the endangered bald eagle from lead poisoning. The court ruled that defendants were in violation of the National Environmental Policy Act and the Endangered Species Act and ordered the areas in question closed to waterfowl hunting for the 1985 season unless only nontoxic shot was used.

In 1986, the National Wildlife Federation again initiated legal action against the U.S. Department of the Interior by filing a motion to permanently enjoin the Department from authorizing the use of lead shot for waterfowl hunting throughout the continental United States beginning with the 1987 season. This case was also filed in the U.S. District Court for the Eastern District of California. The plaintiff argued that by allowing lead shot the defendants were in violation of the Endangered Species Act and the Migratory Bird Treaty Act. At the "eleventh hour," however, the Department of the Interior unveiled a plan to phase out lead shot for waterfowl hunting over a period of several years, culminating in a nationwide ban in 1991 (U.S. Department of the Interior 1986). The court, noting that the defendants had conceded on all aspects of the dispute except timing, dismissed the case for want of ripeness.

In 1987, the California Fish and Game Commission sued the U.S. Department of the Interior in the U.S. District Court for the Eastern District of California. Subsequently, the National Rifle Association intervened in behalf of the plaintiff, and the National Wildlife Federation intervened in behalf of the defendant. The plaintiffs charged that in establishing nontoxic shot zones in California, the Department of the Interior was in violation of the Stevens Amendment, the Tenth Amendment to the U.S. Constitution (States' Rights), the Regulatory Flexibility Act, several conservation statutes, and an executive order protecting wetlands. The wetlands argument was grounded on the premise that the policy of the defendants not to open waterfowl hunting seasons when the plaintiffs failed to approve nontoxic shot regulations would undermine hunter and commercial support for the preservation of waterfowl habitat in California. Supposedly the policy of the Department of the Interior would result in massive reduction of privately owned waterfowl habitat that was also used by endangered

Table 9. Attitudes of waterfowl hunters toward the use of steel shot for waterfowl hunting in Illinois. Data obtained from 1,956 respondents to the 1985 Illinois Waterfowl Hunting Questionnaire (Anderson 1987).

Response	% of Respondents	95% Confidence Interval
Responses to the question, "Which of the following statements best describes your attitude toward the use of nontoxic steel shot for waterfowl hunting in Illinois?"		
I like steel shot, and/or I believe its use is in the best interest of our waterfowl resources.	7.6	± 1.2
I have no objections to steel shot, and I will use it if required by law.	19.4	± 1.7
I don't like steel shot, but I will use it rather than have my areas closed to waterfowl hunting.	62.1	± 2.1
I strongly dislike steel shot, and I would rather have my areas closed to waterfowl hunting than use it.	7.3	± 1.1
No opinion.	3.6	± 0.8

species. The plaintiffs further charged that the defendants' policy of not opening seasons would cause irreparable harm to this wetland habitat and economic damage to local communities and businesses.

In a hearing on 28 September 1987, the court ruled in favor of the Department of the Interior. The court determined that the Stevens Amendment, which was also the vehicle for the Tenth Amendment claim, did not expressly or by implication repeal the authority established under the Endangered Species Act, the Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act. The Department of the Interior, therefore, has the power to protect bald eagles and waterfowl from lead poisoning by not opening hunting seasons in states that do not consent to nontoxic shot regulations. In addition, the court determined that the Department of the Interior had ample scientific evidence of the lead poisoning of waterfowl and endangered species in California and elsewhere in the United States. The court pointed out that if the California Fish and Game Commission chose not to have a hunting season in California, this decision would be a "self-inflicted wound" that the plaintiff itself could reverse; therefore, judicial relief was not warranted. Finally, the court concluded that the National Environmental Protection Act, the Endangered Species Act, and other conservation acts did not require detailed analysis of the effects of not having a waterfowl hunting season because the California Fish and Game Commission was unlikely not to consent to nontoxic shot regulations and because possible harms from no season were remote and speculative. Within 24 hours after the court's ruling, the California Fish and Game Commission voted to consent to the nontoxic shot regulations. After Congress allowed the Stevens Amendment to expire, the California Fish and Game Commission filed a notice of appeal from the court's ruling. The appeal was dismissed on 21 March 1988 on ground of mootness.

Nontoxic Shot Zones

The first nontoxic (steel) shot regulations for waterfowl hunting in Illinois were established with the 1977 hunting season. In that year, waterfowl hunters in 6 counties and on all public hunting areas were required to use steel shot (Table 10). The regulations were expanded in 1978 to cover 14 counties and all public hunting areas. Mounting resistance by waterfowl hunters to steel shot culminated in state legislation (Statute 2.18-1) and the Stevens Amendment. As a result, nontoxic shot regulations were severely curtailed in Illinois with the opening of the 1979 hunting season. Only 2–3% of the state's waterfowl harvest was covered by nontoxic shot zones from 1979 through 1984 (Table 10). Nontoxic shot regulations applied only to 12-gauge shotguns during 1977–1979, to 12- and 10-gauge shotguns in 1980, and to all gauges in 1981 and thereafter.

In response to the 1985 federal court order banning waterfowl hunting unless steel shot was required, nontoxic shot regulations were extended to 10 counties in Illinois. Statute 2.18-1 did not apply because the regulations were established to protect the bald eagle, and not waterfowl, from lead poisoning. The 10 counties, plus the public hunting area at Rend Lake, accounted for 33% of the statewide harvest of waterfowl (Table 11). In 1986, in efforts to expand protection for bald eagles from lead poisoning, the number of counties in nontoxic shot zones was increased and zones along the Mississippi and Illinois rivers modified into corridors (Fig. 9); hunters in these zones harvested 53% of the state's waterfowl (Table 11).

In 1987, after Statute 2.18-1 was amended and as a result of the decision by the U.S. Fish and Wildlife Service not to open the areas in question to waterfowl hunting (*Federal Register* 52:1,638, 15 January 1987), nontoxic shot regulations were applied in 14 counties and in portions of 18 others (Table 11). Counties that were added (or converted from portions to entire counties) complied with the schedule of the Fish and Wildlife Service for total conversion from lead to nontoxic shot for waterfowl hunting by 1991 (U.S. Department of the Interior 1986: Appendix N). The schedule is based on counties with an average harvest of ≥20 waterfowl per square mile (≥7.7 per km^2) for 1987, ≥15 per square mile (≥5.8 per km^2) for 1988, ≥10 per square mile (≥3.9 per km^2) for 1989, ≥5 per square mile (≥1.9 per km^2) for 1990, and all other counties for 1991 (U.S. Department of the Interior 1986:II-13). Seven Illinois counties were affected in 1988 and 4 will be affected in 1989, 21 in 1990, and 52 in 1991 (Table 11, Fig. 9).

Discussion

Findings from the field studies conducted in Illinois demonstrate that lead poisoning in waterfowl occurred throughout the state, that the disease was more prevalent on some areas than on others, and that it was manifested periodically as highly visible die-offs. The findings also show that most groups of waterfowl—dabbling ducks, diving ducks, and geese—are susceptible to lead poisoning, that the disease has not decreased in severity since 1938–1954, and that most monitoring programs underestimate its magnitude in wild populations. Because lead poisoning is caused by waterfowl ingesting spent lead pellets, the cure is straightforward and effective—replace toxic lead shot with nontoxic steel shot for waterfowl hunting.

The data on shot ingestion make clear that waterfowl are exposed to lead poisoning on virtually all areas where they are hunted in Illinois (Tables 2–4). Ingested shot was found in mallards on 28 of the 29 areas that were sampled, in lesser scaups on 5 of 8 areas, and in Canada geese on 3 of 3 areas. The only areas where ingested shot was not found were those represented by small sample sizes (<20 gizzards).

If we use the 5.0% incidence of ingested shot in gizzards of hunter-harvested birds as the threshold for "excessive" lead poisoning in waterfowl populations (U.S. Department of the Interior 1986:H-10), the following areas can be identified as having the most severe problems: Pool 12, Pool 16, and Pool 25 on the Mississippi River; Peoria Pool, La Grange Pool, and Pool 26 on the Illinois River; Heidecke Lake in Grundy County; wetland habitats in McHenry County; Fish Hook Subimpoundment at Shelbyville Lake; Horseshoe Lake in Madison County; Oakwood Bottoms in Jackson County; and Canada goose habitat in the vicinity of Horseshoe Lake and Union County refuges (Tables 2–4). However, in blood samples from eight waterfowl populations on seven areas, the incidences of above-background concentrations of lead in blood averaged 6–10 times greater than the incidence of ingested lead shot; further, concentrations of lead in

Table 10. Counties, public hunting areas, and gauges of shotguns subject to nontoxic shot regulations for waterfowl hunting, and the percentage of the statewide waterfowl harvest taken in nontoxic shot zones in Illinois, 1977–1984 hunting seasons. EC = entire county. From 1979 through 1984 no entire counties were covered by nontoxic shot regulations.

County or Parameter	1977	1978	1979	1980	1981	1982	1983	1984
Mississippi River								
Jo Daviess		EC						
Carroll		EC						
Rock Island	EC	EC						
Henderson	EC	EC						
Pike [a]		EC						
Calhoun [a]	EC	EC						
Illinois River								
Putnam	EC	EC						
Marshall	EC	EC						
Woodford		EC						
Mason		EC						
Cass		EC						
Jersey	EC	EC						
Pike		EC						
Calhoun	EC	EC						
North and Northeast								
Lake		EC						
McHenry		EC						
Public hunting areas	all [b]	all [b]	6 [c]	6 [c]	5 [d]	5 [d]	5 [d]	5 [d]
Percentage of statewide harvest in nontoxic shot zones	18 [e]	32 [e]	3 [e]	3 [e]	2 [e]	2 [e]	2 [e]	2 [e]
Gauges of shotguns	12	12	12	12&10	all [f]			

[a] Listed under both Mississippi and Illinois rivers.

[b] All state and federally owned and/or managed public waterfowl hunting areas.

[c] Horseshoe Lake in Alexander County, Union County, Oakwood Bottoms, Rice Lake, Crab Orchard, and Stump Lake.

[d] Horseshoe Lake in Alexander County, Union County, Oakwood Bottoms, Rice Lake, and Crab Orchard.

[e] These values do not equate to the percentage of the statewide harvest taken with nontoxic shot because nontoxic shot was not required for all gauges of shotguns in 1977–1980 and because some hunters used nontoxic shot in areas where it was not required.

[f] Nontoxic shot regulations applied to all gauges of shotguns in 1981 and thereafter.

Table 11. Schedule for converting counties (or portions of counties) to nontoxic shot for waterfowl hunting, and the percentage of the statewide waterfowl harvest taken in nontoxic shot zones in Illinois, 1985–1991 hunting seasons. Cor = corridor along river, EC = entire county, P = portion of county as described in footnote. In 1991 nontoxic shot regulations will apply statewide.

County or Parameter [a]	1985	1986	1987	1988	1989	1990	1991 Statewide
Upper Mississippi River							
Jo Daviess		Cor [b]				EC →	
Carroll		Cor	EC →				
Whiteside		Cor				EC →	
Rock Island		Cor			EC →		
Mercer		P [c]				EC →	
Henderson	EC	Cor	EC →				
Hancock		Cor				EC →	
Adams		P [d]					EC
Pike [e]	EC	Cor			EC →		
Calhoun [e]	EC	Cor	EC →				
Illinois River							
Grundy						EC →	
Bureau		Cor [f]				EC →	
Putnam		Cor	EC →				
Marshall		Cor		EC →			
Woodford		Cor		EC →			
Peoria	EC	Cor			EC →		
Tazewell		Cor				EC →	
Fulton	EC →						
Mason	EC	Cor	EC →				
Cass		Cor	EC →				
Schuyler		Cor					EC
Brown		Cor					EC
Morgan		P [g]					EC
Greene		P [h]				EC →	
Jersey		Cor		EC →			
Pike [e]	EC	Cor			EC →		
Calhoun [e]	EC	Cor	EC →				
North and Northeast							
Lake			EC →				
McHenry				EC →			
Kane				EC →			
Will						EC →	
Cook						EC →	
DuPage						EC →	
Kendall						EC →	
Winnebago						EC →	
Central and Southern							
Clinton			EC →				
Bond				EC →			
Fayette				EC →			
Jefferson	P [i]		EC →				
Franklin	P [i]				EC →		
Moultrie						EC →	
Coles						EC →	
Christian						EC →	
Madison						EC →	
St. Clair						EC →	

Table 11 continued.

County or Parameter	1985	1986	1987	1988	1989	1990	1991 Statewide
Monroe						EC →	
Randolph						EC →	
Perry						EC →	
Alexander	EC →						
Union	EC →						
Jackson	EC →						
Williamson	EC →						
Percentage of statewide harvest in nontoxic shot zones	33	53	64	74	75	90	100

[a] The 52 counties (or portions of counties) not listed are scheduled for conversion in 1991.
[b] Corridor extended from Wisconsin state line to IL-92 bridge west of Illinois City, from Keithsburg to Lock and Dam 20 at Meyer, and from East Hannibal to Grafton.
[c] South of railroad bridge at Keithsburg and west of county highways 16 and 25.
[d] Bear Creek Unit of Mark Twain National Wildlife Refuge.
[e] Listed under both Mississippi and Illinois rivers.
[f] Corridor extended from Spring Valley to Meredosia and from Kampsville to Grafton.
[g] North of IL-104 and west of IL-100.
[h] South of IL-108 and west of Federal-Aid Primary Route 155.
[i] Rend Lake Public Hunting Area.

blood were always ≥5.0% (Table 7). These findings take on added importance when we consider that above-background concentrations of lead in blood are closely associated with biochemical anomalies in waterfowl (Finley et al. 1976; Dieter and Finley 1978; Dieter 1979). From this information, we conclude that the actual prevalence of lead poisoning in waterfowl, as measured by concentrations of lead in blood and other sensitive techniques, was excessive in virtually all populations in Illinois.

The presence of ingested steel shot in gizzards indicates that exposure to lead poisoning may well have been reduced 20–25% in waterfowl in Illinois during the 1979–1985 period (Table 6). These values are much greater than the percentage of the statewide waterfowl harvest covered by nontoxic shot regulations during six of the seven years (Tables 10 and 11). The difference is explained, at least in part, by the fact that many hunters were voluntarily using steel shot for waterfowl hunting; an estimated 12.0% of the statewide harvest was taken with steel shot in 1984 (Anderson 1986a).

On areas where nontoxic shot was used extensively for waterfowl hunting, the percentage of ingested shot that was steel averaged 46.2 for mallards and 25.0 for Canada geese (Table 6). On areas where lead shot was the primary load used for hunting, the percentage of ingested shot that was steel averaged 17.7 and 0.0, respectively, for the same two species. The failure to find ingested steel shot in Canada geese harvested on the Horseshoe Lake Public Hunting Area is not surprising because >90% of the goose harvest in Alexander County took place on private areas (Thornburg 1986), where lead shot was used during the years gizzards were collected. In mallards harvested in 13 states in the Mississippi Flyway, the percentage of ingested shot that was steel was directly related to the use of nontoxic shot and indirectly related to the use of lead shot (Anderson et al. 1987). The ingestion of steel shot by waterfowl—and therefore the reduction in lead poisoning—is closely associated with the use of steel shot for waterfowl hunting.

Although the 13 documented cases of lead poisoning die-offs of waterfowl in Illinois in 1977–1988 evoked strong emotional responses from biologists and sportsmen alike, such deaths represent only a small proportion of all birds falling victim to the disease. Sick birds seek isolation and dense cover (Sanderson and Bellrose 1986) and, consequently, are difficult to find (Humburg et al. 1983; Stutzenbaker et al. 1983). To quote Sanderson and Bellrose (1986:16–17):

> Dead ducks are seldom noticed in the marsh, and most hunters are unaware of the extensive losses of waterfowl caused by lead poisoning. Nevertheless, banding data indicate that approximately one-fourth of all ducks alive in September die from *natural causes* within the year—slightly more than are killed by hunters. The fall population of game ducks is usually around 90,000,000, although it declined to about 62,000,000 in 1985. With a natural mortality rate of 22.2 percent, a minimum of

> 14,000,000 to 20,000,000 of these ducks can be expected to die from natural causes each year [emphasis in original].

These deaths remain inconspicuous as long as the number of birds dying do not exceed the capabilities of scavengers and predators to remove or consume the carcasses.

None of the six lawsuits challenging state and federal nontoxic shot regulations was successful. Conversely, one of the two lawsuits seeking expansion of nontoxic shot zones was successful and one was dismissed on the grounds that it was premature. The courts have consistently accepted the scientific evidence that establishes lead poisoning as a serious problem in waterfowl, and they have consistently rejected arguments that steel shot is ballistically inferior to lead shot, cripples excessively, and damages firearms (Feierabend 1985). For reviews of the performance of steel shot compared to lead shot, see U.S. Department of the Interior (1986:III-86–90) and Sanderson and Bellrose (1986:23–28).

Statute 2.18-1 of the Illinois Conservation Laws mandated restrictive procedures for establishing nontoxic shot regulations in the state. As a result, the Department of Conservation was forced to abandon most of the nontoxic shot areas that were in effect in 1978 and able to add only one area (Rend Lake Public Hunting Area) from 1979 to 1985 (Tables 10 and 11). However, the wording of Statute 2.18-1 proved too restrictive in 1987 when it became clear that, in the absence of an amendment, the statute would prevent the Department of Conservation from approving additional nontoxic shot zones within the state. Although the Stevens Amendment prevented the U.S. Fish and Wildlife Service from imposing nontoxic shot zones, the Fish and Wildlife Service maintained that

> If States do not approve nontoxic shot zones when current FWS guidelines and criteria indicate that such zones are necessary to protect migratory birds, the FWS will not open the areas to waterfowl and coot hunting. This action is taken pursuant to the FWS' responsibilities under the Migratory Bird Treaty Act and, in the case of zones established for bald eagle protection, the Endangered Species Act and the Bald and Golden Eagle Protection Act. . . .(*Federal Register* 52:1,638, 15 January 1987).

Fortunately, Statute 2.18-1 was amended and the additional nontoxic shot zones were printed in the *Federal Register* on 25 August 1987—seven days before the 1987 waterfowl hunting season began. The amendment reflected the sentiments of most waterfowl hunters (Table 9).

The history of Statute 2.18-1 of the Illinois Conservation Laws offers a classic example of how narrowly designed legislation can be counterproductive to sport hunting and to the proper management of wildlife resources on a long-term basis. As stated by Feierabend (1985:458),

> Legislation that disrupts state nontoxic shot programs not only invites closure of seasons by the Federal government, but promotes wildlife management through political consensus rather than sound biological reasoning. Sportsmen, biologists, and administrators have historically opposed empowering state legislatures to render conservation decisions. Legislation to establish, limit, and remove nontoxic shot zones is no different than legislation to establish season lengths, bag limits, or other equipment restrictions. Attempts to legislatively compromise administrators' authority to manage wildlife resources should be opposed, regardless of the issue.

Nontoxic shot will be required for all sport hunting of waterfowl in Illinois beginning with the 1991 season. As duck and goose populations have declined and breeding, migration, and wintering habitats have

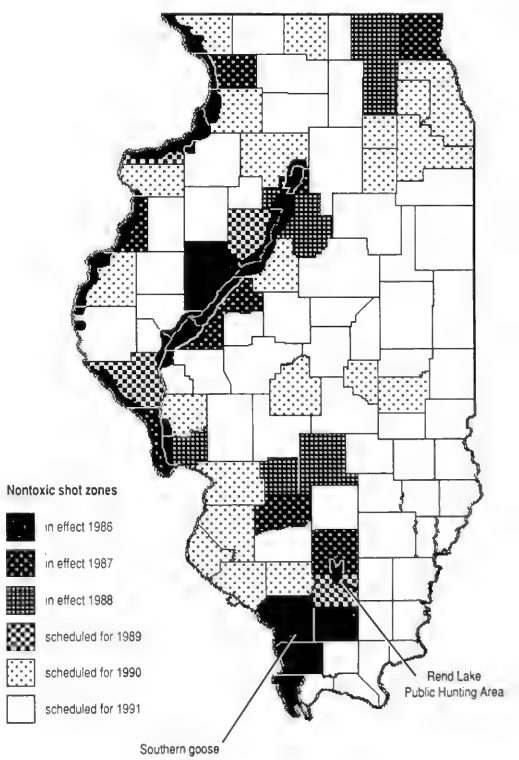

FIGURE 9. Conversion by counties or portions of counties to nontoxic shot for waterfowl hunting, 1986-1991 seasons.

disappeared or been degraded, regulations have been modified to protect waterfowl resources. The elimination of spring shooting, baiting, and the use of live decoys and the implementation of the three-shell limit for shotguns were all major changes to the sport hunting of waterfowl. Other than changes in bag limits and season lengths, no major regulations have been adopted since the mid-1930s. Future generations of waterfowl hunters will undoubtedly appreciate the efforts that resulted in the implementation of nontoxic shot regulations, thereby eliminating the major man-induced disease in waterfowl populations.

Summary

Lead poisoning in waterfowl was investigated in Illinois during 1977–1988 by determining the incidence of spent shot in soil and sediment, by examining gizzards for ingested shot, by analyzing blood for concentrations of lead and protoporphyrin and livers for concentrations of lead, and by documenting die-offs from the disease. Spent shot averaged 37,700 pellets per acre (93,155 per ha) in soil and sediment in the Casey Fork Subimpoundment at Rend Lake. Ingested shot (both lead and steel) in gizzards of birds harvested throughout the state averaged 5.9% in 13,779 mallards, 6.9% in 1,385 lesser scaups, and 5.6% in 887 Canada geese. The proportion of ingested shot that was steel averaged 20.9% for mallards throughout the state and 46.2% on areas where nontoxic shot was used extensively. Incidences of above-background concentrations of lead in livers and of protoporphyrin in blood were similar to incidences of ingested lead shot in gizzards; however, incidences of above-background concentrations of lead in blood averaged 6–10 times greater than the incidences of ingested shot. The prevalence of lead poisoning in waterfowl was ≥5.0% in most populations in Illinois. Thirteen cases of lead poisoning die-offs of waterfowl were documented in Illinois during 1977–1988.

Nontoxic shot regulations for waterfowl hunting in Illinois were hampered by two statutes: the Stevens Amendment, which required the U.S. Fish and Wildlife Service to secure the approval of state authorities before implementing or enforcing nontoxic shot zones in a state, and Statute 2.18-1 of the Illinois Conservation Laws, which severely restricted the latitude of the Illinois Department of Conservation in establishing nontoxic shot zones. Six law suits unsuccessfully challenged state and federal nontoxic shot regulations, and one successfully argued for the expansion of nontoxic shot zones to protect the endangered bald eagle from lead poisoning. In 1986, the Fish and Wildlife Service unveiled plans for a nationwide phase-out of lead shot for waterfowl hunting that will culminate in 1991, adopting the policy that "If states do not approve nontoxic shot zones when current FWS guidelines and criteria indicate that such zones are necessary to protect migratory birds, the FWS will not open the areas to waterfowl and coot hunting. . . ." Statute 2.18-1 came within seven days of preventing the opening of some areas to waterfowl hunting in Illinois in 1987. As was demonstrated in this case, narrowly conceived legislation can be detrimental to sport hunting and to the successful management of wildlife resources.

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Appendix A. Common and scientific names of species of fish, birds, and plants mentioned in the text and tables, arranged in taxonomic order.

Common Name	Scientific Name	Common Name	Scientific Name
Fish		Greater scaup	*A. marila*
Gizzard shad	*Dorosoma cepedianum*	Lesser scaup	*A. affinis*
		Common goldeneye	*Bucephala clangula*
Birds		Ruddy duck	*Oxyura jamaicensis*
Canada goose	*Branta canadensis*	Bald eagle	*Haliaeetus leucocephalus*
Mallard	*Anas platyrhynchos*	Bobwhite	*Colinus virginianus*
Black duck	*A. rubripes*	Pheasant	*Phasianus colchicus*
Gadwall	*A. strepera*	American coot	*Fulica americana*
American wigeon	*A. americana*	Gull	*Larus* spp.
Northern pintail	*A. acuta*	Mourning dove	*Zenaidura macroura*
Green-winged teal	*A. crecca*		
Blue-winged teal	*A. discors*	Plants	
Northern shoveler	*A. clypeata*	Japanese millet	*Echinochloa frumentacea*
Wood duck	*Aix sponsa*	Milo	*Sorghum vulgare*
Redhead	*Aythya americana*	Corn	*Zea mays*
Ring-necked duck	*A. collaris*	Buckwheat	*Fagopyrum esculentum*
Canvasback	*A. valisineria*	Sunflower	*Helianthus* spp.

Appendix B. Incidence of ingested shot in waterfowl harvested on each area in Illinois, 1979–1985 hunting seasons.

Table B-1. Incidence of ingested shotgun pellets in mallards harvested on areas along the Mississippi River in Illinois, 1979–1985 hunting seasons.

Area	Year	Number of Gizzards	Number of Gizzards with Pellets				%
			Lead	Steel	Both	Total	
Pool 12	1981	51	1	0	0	1	2.0
	1982	2	0	0	0	0	—[a]
	1983	43	1	1	2	4	9.3
Total		96	2	1	2	5	5.2
Pool 13							
Big Slough Access	1979	44	4	0	0	4	9.1
Potter's Marsh	1980	2	0	0	0	0	—
	1981	57	0	1	0	1	1.8
	1982	302	6	1	1	8	2.6
	1985	103	8	2	0	10	9.7
Total		464	14	4	1	19	4.1
Other areas	1981	329	11	5	1	17	5.2
	1982	359	8	3	1	12	3.3
Total		688	19	8	2	29	4.2
All areas	1979	44	4	0	0	4	9.1
	1980	2	0	0	0	0	—
	1981	386	11	6	1	18	4.7
	1982	661	14	4	1	10	3.0
	1985	103	8	2	0	10	9.7
Total		1,196	37	12	3	52	4.3

Table B-1 continued.

Area	Year	Number of Gizzards	Number of Gizzards with Pellets				%
			Lead	Steel	Both	Total	
Pool 16	1980	68	1	0	0	1	1.5
	1981	75	5	0	0	5	6.7
	1982	152	9	0	0	9	5.9
Total		295	15	0	0	15	5.1
Pool 17	1981	65	1	0	0	1	1.5
	1982	218	3	0	0	3	1.4
Total		283	4	0	0	4	1.4
Pool 18	1980	53	0	1	0	1	1.9
	1981	227	6	0	0	6	2.6
Total		280	6	1	0	7	2.5
Pool 21	1980	64	2	0	0	2	3.1
	1981	20	0	1	0	1	—
	1982	19	0	0	0	0	—
	1983	37	0	0	0	0	—
Total		140	2	1	0	3	2.1
Pool 22	1980	28	0	0	0	0	—
	1982	8	0	0	0	0	—
	1983	59	0	1	0	1	1.7
Total		95	0	1	0	1	1.1
Pool 24							
Neiswender Duck Club	1979	41	0	0	0	0	0.0
	1980	13	0	0	0	0	—
Total		54	0	0	0	0	0.0
Log Slough Duck Club	1979	53	0	0	0	0	0.0
	1980	59	1	1	0	2	3.4
Total		112	1	1	0	2	1.8
Half Moon Duck Club	1980	12	1	0	0	1	—
Fenup Duck Club	1980	137	4	1	0	5	3.6
Other areas	1980	214	3	0	0	3	1.4
	1983	6	0	0	0	0	—
Total		220	3	0	0	3	1.4
All areas	1979	94	0	0	0	0	0.0
	1980	435	9	2	0	11	2.5
	1983	6	0	0	0	0	—
Total		535	9	2	0	11	2.1
Pool 25							
Batchtown (public hunting area)	1979	150	23	2	0	25	16.7
	1980	265	11	2	1	14	5.3
	1981	161	7	1	0	8	5.0
Total		576	41	5	1	47	8.2

[a] Not calculated because of small sample size.

Table B-2. Incidence of ingested shotgun pellets in mallards harvested on areas along the Illinois River in Illinois, 1979–1985 hunting seasons.

Area	Year	Number of Gizzards	Number of Gizzards with Pellets				
			Lead	Steel	Both	Total	%
Peoria Pool							
Lake Depue (public hunting area)	1979	97	8	1	2	11	11.3
	1980	130	4	0	0	4	3.1
Total		227	12	1	2	15	6.6
Windblown Bottoms Duck Club	1979	36	2	0	0	2	—[a]
Senachwine Duck Club	1979	313	16	2	0	18	5.8
	1980	174	7	1	0	8	4.6
Total		487	23	3	0	26	5.3
Commercial picker in Henry	1979	299	22	6	3	31	10.4
Marshall County (public hunting area)	1979	127	6	0	1	7	5.5
	1980	194	9	2	0	11	5.7
Total		321	15	2	1	18	5.6
Woodford County (public hunting area)	1979	224	19	5	1	25	11.2
	1985	150	4	1	0	5	3.3
Total		374	23	6	1	30	8.0
Mallard Farms Duck Club	1979	221	9	6	2	17	7.7
	1980	261	3	7	0	10	3.8
Total		482	12	13	2	27	5.6
All areas	1979	1,317	82	20	9	111	8.4
	1980	759	23	10	0	33	4.3
	1985	150	4	1	0	5	3.3
Total		2,226	109	31	9	149	6.7
La Grange Pool							
Spring Lake (public hunting area)	1979	105	10	1	0	11	10.5
	1980	24	1	0	0	1	—
	1981	273	8	2	0	10	3.7
Total		402	19	3	0	22	5.5
Commercial picker in Manito	1979	262	13	2	1	16	6.1
	1980	270	17	2	0	19	7.0
Total		532	30	4	1	35	6.6
Rice Lake (public hunting area)	1979	19	2	0	0	2	—
	1980	17	0	0	0	0	—
	1981	79	3	0	0	3	3.8
	1982	50	0	1	0	1	2.0
Total		165	5	1	0	6	3.6[b]
Grand Island Duck Club	1979	119	17	1	1	19	16.0
	1980	207	22	2	1	25	12.1
Total		326	39	3	2	44	13.5
Anderson Lake (public hunting area)	1979	38	1	0	0	1	—
	1980	56	9	3	0	12	21.4
	1981	66	6	0	0	6	9.1
	1982	137	3	0	0	3	2.2
Total		297	19	3	0	22	7.4
Crane Lake Duck Club	1979	254	33	4	1	38	15.0
	1980	233	23	5	0	28	12.0
Total		487	56	9	1	66	13.6
Sanganois (public hunting area)	1979	70	14	0	0	14	20.0
	1980	118	16	5	0	21	17.8
	1981	144	6	1	0	7	4.9
Total		332	36	6	0	42	12.7

Table B-2 continued.

Area	Year	Number of Gizzards	Number of Gizzards with Pellets				%
			Lead	Steel	Both	Total	
Wilcox Lake Duck Club	1980	144	6	0	1	7	4.9
	1983	55	2	0	0	2	3.6
Total		199	8	0	1	9	4.5
All areas	1979	867	90	8	3	101	11.6
	1980	1,069	94	17	2	113	10.6
	1981	562	23	3	0	26	4.6
	1982	187	3	1	0	4	2.1
	1983	55	2	0	0	2	3.6
Total		2,740	212	29	5	246	9.0
Pool 26 [c]							
Honey Point Duck Club	1983	112	5	2	0	7	6.3
Taylor Lake Duck Club	1981	18	2	0	0	2	—
	1982	26	1	0	0	1	—
Total		44	3	0	0	3	6.8
Godar/Diamond (public hunting area)	1979	113	12	0	0	12	10.6
	1980	146	3	0	1	4	2.7
Total		259	15	0	1	16	6.2
Glades (public hunting area)	1979	78	6	0	0	6	7.7
	1980	81	6	0	1	7	8.6
	1981	75	1	0	0	1	1.3
Total		234	13	0	1	14	6.0
Stump Lake (public hunting area)	1979	85	4	1	0	5	5.9
	1980	96	2	1	1	4	4.2
	1981	17	0	0	0	0	—
	1982	18	0	2	0	2	—
	1985	100	9	1	0	10	10.0
Total		316	15	5	1	21	6.6
Calhoun Point (public hunting area)	1979	24	1	0	0	1	—
	1980	32	1	1	0	2	—
	1981	52	1	1	0	2	3.8
	1982	28	3	0	0	3	—
	1983	148	5	2	0	7	4.7
Total		284	11	4	0	15	5.3
All areas	1979	300	23	1	0	24	8.0
	1980	355	12	2	3	17	4.8
	1981	162	4	1	0	5	3.1
	1982	72	4	2	0	6	8.3
	1983	260	10	4	0	14	5.4
	1985	100	9	1	0	10	10.0
Total		1,249	62	11	3	76	6.1

[a] Not calculated because of small sample size.

[b] Biased toward low value because ≥83% of the gizzards were collected during the first 3 weeks of the hunting season when less spent shot is available.

[c] The lower part of the Illinois River is under the influence of Lock and Dam 26 on the Mississippi River.

Table B-3. Incidence of ingested shotgun pellets in mallards harvested on areas in northeastern Illinois, 1980–1983 hunting seasons.

Area	Year	Number of Gizzards	Number of Gizzards with Pellets				%
			Lead	Steel	Both	Total	
McHenry County							
Bull Valley Duck Club	1980	50	3	0	0	3	6.0
Fox Lake (public hunting area)	1983	24	0	0	0	0	—[a]
Fox River	1983	6	1	0	0	1	—
All areas	1980	50	3	0	0	3	6.0
	1983	30	1	0	0	1	—
Total		80	4	0	0	4	5.0
Kane County							
Kane County Marsh Duck Club	1981	9	0	0	0	0	—
	1982	28	0	0	0	0	—
	1983	37	1	0	0	1	—
Total		74	1	0	0	1	1.4
McGraw Duck Club	1982	74	2	0	0	2	2.7
	1983	73	4	0	0	4	5.5
Total		147	6	0	0	6	4.1
All areas	1981	9	0	0	0	0	—
	1982	102	2	0	0	2	2.0
	1983	110	5	0	0	5	4.5
Total		221	7	0	0	7	3.2
Cook County							
Calumet Lake	1981	2	0	0	0	0	—
Hoffman Estates	1983	16	0	0	0	0	—
Total		18	0	0	0	0	—
Will County							
Bass 'n Gill Duck Club	1981	42	1	2	0	3	7.3
	1982	12	0	0	0	0	—
	1983	26	0	0	0	0	—
Total		80	1	2	0	3	3.8
Grundy County							
Heidecke Lake (public hunting area)	1981	155	6	1	0	7	4.5
	1982	114	1	1	0	2	1.8
Total		269	7	2	0	9	3.3
Coal City Duck Club	1981	21	0	1	0	1	—
	1982	4	0	0	0	0	—
	1983	3	0	0	0	0	—
Total		28	0	1	0	1	—
All areas	1981	176	6	2	0	8	4.5
	1982	118	1	1	0	2	1.7
	1983	3	0	0	0	0	—
Total		297	7	3	0	10	3.4

[a] Not calculated because of small sample size.

Table B-4. Incidence of ingested shotgun pellets in mallards harvested on areas in central and southern Illinois, 1979–1985 hunting seasons.

Area	Year	Number of Gizzards	Number of Gizzards with Pellets				%
			Lead	Steel	Both	Total	
Sangchris Lake (public hunting area)	1979	230	3	2	0	5	2.2
	1980	122	5	0	0	5	4.1
	1981	98	1	1	0	2	2.0
Total		450	9	3	0	12	2.7
Shelbyville Lake (public hunting area)	1984	4	0	0	0	0	—[a]
	1985	38	1	0	0	1	—
Total		42	1	0	0	1	2.4
Carlyle Lake (public hunting area)	1979	148	3	0	0	3	2.0
	1980	138	5	1	0	6	4.3
	1981	86	5	0	0	5	5.8
Total		372	13	1	0	14	3.8
Rend Lake (public hunting area)	1979	77	1	0	0	1	1.3
	1980	72	3	0	0	3	4.2
	1981	44	4	1	0	5	11.4
	1982	243	6	1	1	8	3.3
	1983	310	10	1	0	11	3.5
	1984	138	3	1	0	4	2.9
Total		884	27	4	1	32	3.6
Monroe County	1982	153	3	1	0	4	2.6
	1983	160	6	1	0	7	4.4
Total		313	9	2	0	11	3.5
Kaskaskia River (public hunting area)	1980	25	0	1	0	1	—
	1981	173	2	1	1	4	2.3
Total		198	2	2	1	5	2.5
Mermet Lake (public hunting area)	1979	162	4	1	0	5	3.1
	1980	118	5	1	1	7	5.9
Total		280	9	2	1	12	4.3
Oakwood Bottoms (public hunting area)	1980	98	4	1	0	5	5.1
	1981	110	6	5	1	12	10.9
Total		208	10	6	1	17	8.2
Horseshoe Lake[b]							
Public hunting area	1980	45	0	3	1	4	8.9
	1981	28	3	0	0	3	—
	1982	125	24	3	1	28	22.4
	1983	22	2	0	0	2	—
Total		220	29	6	2	37	16.8
Nichols Duck Club	1981	100	2	5	0	7	7.0
	1982	58	6	4	0	10	17.2
	1983	247	8	7	0	15	6.1
Total		405	16	16	0	32	7.9
All areas	1980	45	0	3	1	4	8.9
	1981	128	5	5	0	10	7.8
	1982	183	30	7	1	38	20.8
	1983	269	10	7	0	17	6.3
Total		625	45	22	2	69	11.0

[a] Not calculated because of small sample size.
[b] Madison County.

Table B-5. Incidence of ingested shotgun pellets in lesser scaups, redheads, and ring-necked ducks harvested on areas in Illinois, 1979–1985 hunting seasons.

Area	Year	Number of Gizzards	Number of Gizzards with Pellets				
			Lead	Steel	Both	Total	%
Lesser Scaups							
Mississippi River							
Pool 16	1982	19	0	0	0	0	—[a]
Pool 18	1985	12	0	0	0	0	—
Pool 19	1979	19	0	0	0	0	—
	1980	51	1	0	0	1	2.0
	1981	150	0	0	0	0	0.0
	1982	158	4	0	0	4	2.5
	1983	69	3	0	0	3	4.3
	1984	20	1	1	0	2	—
	1985	510	14	9	2	25	4.9
Total		977	23	10	2	35	3.6
Lake Michigan	1980	7	0	0	0	0	—
	1981	2	0	0	0	0	—
	1982	15	2	0	0	2	—
Total		24	2	0	0	2	—
Calumet Lake	1981	4	0	0	0	0	—
Heidecke Lake	1981	34	2	2	1	5	—
	1982	41	0	0	0	0	0.0
	1983	47	2	0	0	2	4.3
Total		122	4	2	1	7	5.7
Shelbyville Lake (public hunting area)	1984	87	39	1	4	44	50.6
	1985	3	1	0	0	1	—
Total		90	40	1	4	45	50.0
Horseshoe Lake[b]	1981	69	2	0	0	2	2.9
	1982	29	2	0	0	2	—
	1983	39	3	0	0	3	—
Total		137	7	0	0	7	5.1
Redheads							
Mississippi River							
Pool 19	1980	13	0	0	0	0	—
	1981	5	0	0	0	0	—
	1982	11	0	0	0	0	—
	1983	8	0	0	0	0	—
Total		37	0	0	0	0	0.0
Ring-necked Ducks							
Mississippi River							
Pool 18	1985	4	0	0	0	0	—
Pool 19	1981	5	0	0	0	0	—
	1982	3	0	0	0	0	—
	1985	46	3	2	0	5	10.9
Total		58	3	2	0	5	8.6
Shelbyville Lake (public hunting area)	1984	16	0	1	0	1	—
	1985	9	0	0	0	0	—
Total		25	0	1	0	1	—

[a] Not calculated because of small sample size.
[b] Madison County.

Table B-6. Incidence of ingested shotgun pellets in Canada geese harvested on areas in Illinois, 1981–1984 hunting seasons.

Area	Year	Number of Gizzards	Number of Gizzards with Pellets				
			Lead	Steel	Both	Total	%
Rend Lake	1981	88	0	0	0	0	0.0
	1982	73	1	0	0	1	1.4
	1983	9	1	0	0	1	—[a]
Total		170	2	0	0	2	1.2
Union County Refuge	1982	184	3	2	1	6	3.3
	1984	154	7	9	0	16	10.4
Total		338	10	11	1	22	6.5
Horseshoe Lake Refuge[b]	1982	172	14	0	0	14	8.1
	1984	207	12	0	0	12	5.8
Total		379	26	0	0	26	6.9

[a] Not calculated because of small sample size.
[b] Alexander County.

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